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# HERPETOFAUNA

Volume 32 Number 2

December 2002



Female Inland Carpet Python (*Morelia spilota metcalfei*). See paper on page 85.  
(Photo by G. Heard).



Prickly Forest Skink (*Gnypetoscincus queenslandiae*) from Atherton Tableland.  
See paper on page 95. (Photo by G. Shea).

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ISSN 0725-1424

Printed by Little Green Frog Print, Sydney (02) 9439 6122

# ARBOREAL SLEEP SITE SELECTION IN *SAPROSCINCUS BASILISCUS* (SCINCIDAE)

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## INTRODUCTION

*Saproscincus basiliscus* (Ingram & Rawlinson, 1981) is small (max SVL < 50 mm), terrestrial, diurnal skink endemic to the rain forests of north eastern Queensland (16°02'S-19°28'S). The natural history of *Saproscincus* spp. is poorly known (see Greer, 1989; Hutchinson, 1993; Heatwole & Pianka, 1993). As a group, they prefer shaded, moist microhabitats. They live amongst leaf litter, under and around rocks and logs, and the lower trunks of buttressed trees (Wilson & Knowles, 1988; Greer, 1989; Ehmann, 1992). The few published details that do exist on the habits of *S. basiliscus* (e.g., Ehmann, 1992: 257) predate changes to the species delineation (Couper & Keim, 1998). Hence, in the absence of locality data, these observations can not be reliably ascribed to *S. basiliscus*.

We report on a curious behaviour in *S. basiliscus*. This normally terrestrial lizard has been observed sleeping perched on the terminal leaves of vegetation. Anthony (1996, 1997, 1999) first recorded this behaviour at one locality (Nandroya Falls; see Observation 3 below). In subsequent field surveys of stream-dwelling frogs of the area, he included a count of the numbers of sleeping *S. basiliscus* observed. In this work we describe this behaviour in detail, report on its occurrence at other localities and examine several possible explanations for its significance.

## METHODS

Observations occurred incidentally over several years in the course of walking along trails and watercourses at night through rain forest in the Wet Tropics. *S. basiliscus* was not specifically targeted during the walks but

other reptiles and frogs were. By the use of small headlamps and spotlights the skinks were easily seen lying asleep on vegetation beside trails. Latitudes and longitudes were estimated (to the nearest 30'') from 1:50,000 topographic maps (Series R733 Bartle Frere, Mena Creek, Innisfail, Cooper Point) and altitude was estimated to the nearest 50 m from topographic maps, where the precise location was known. Temperatures quoted refer to those taken on site to the nearest 1°C. The height of skinks above the ground was estimated to the nearest 0.1 m.

## OBSERVATIONS

### General

*S. basiliscus* were particularly common close to watercourses. Skinks lay in an out-stretched posture with the head, body and tail virtually in a straight line; none were observed curled-up and only a few were seen with the tail curled back along the body. If the leaf was smaller than the length of the skink, the tail was typically left to dangle over the edge. Occasionally skinks perched on terminal branches rather than leaves. The usual orientation of skinks on vegetation was for the head to point back towards the stem of the plant, suggesting that they must, at the end of their climb, turn-around. Whatever the orientation, the head was higher, or at least level with, the body. Most skinks opened their eyes when exposed to torchlight. Any slight disturbance of the plant (stem or leaf) on which they rested usually resulted in them leaping to the ground and disappearing in amongst ground litter. No individuals were ever observed sleeping on the ground. On numerous occasions two individuals were observed in close proximity on separate leaves of the same plant. Skinks were often recorded



asleep on plants occupied by the two stream dwelling frog species: Common Mist Frog *Litoria rheocola*, and to a lesser extent, New Guinea Tree Frog *Litoria genimaculata*.

A variety of plants was selected as sleep sites with ferns and broad-leaved saplings being commonly used. In most instances the thickness of the stem of the plant selected did not exceed 20 mm and in the case of adult skinks it was not unusual for stems to be smaller than the width of the skink. Palms, primarily the Scrub Breadfruit palm *Pandanus monticola*, and Wait-a-While *Calamus motii* were also occasionally used (see Observation 1 & 4 below). Despite being very common along trails, Native Torch Ginger *Tapeinocheilos ananassae* was infrequently used by skinks. This may be due to the smoothness of the stem and the wide gaps between its large leaves (relative to the length of *S. basiliscus*) which may have made climbing difficult.

While *S. basiliscus* is generally regarded as being terrestrial by day, there is some evidence to suggest that they climb low vegetation during daylight hours. We have often observed the species on the top of shaded, low (<0.5 m) herbs and ferns, particularly *Polia macrophylla* and the fern-like *Selaginella longipinna* that forms 'carpets' in shaded sites and is especially common along water-courses. The latter species was one of several 'ferns' that *S. basiliscus* also utilised at night. Skinks were typically seen alighting from the flat-topped fronds of these ferns into the undergrowth during daylight hours.

The following observations of *S. basiliscus* asleep on vegetation at night represent a selection from a variety of locations, elevations and times of the year, rather than an exhaustive list of all observations.

1. Alligator Creek, Mt Elliot (19°28'S 146°57'E), 35 km SE of Townsville.

10 April 1999, approx. 900 m alt. Four adults were seen perched 0.5 to 2 m above the ground asleep; two of these had their heads pointing back towards the trunk and tail draping down. Three were on large leaves of

saplings while the fourth was located 2 m above the ground at the very tip of a mature She-oak *Allocasuarina* sp., where it clung tenaciously to the terminal leaves in blustery conditions. This particular lizard must have climbed up the trunk and then 1.5 m out along the branch to the tip.

2. Disused logging trail, Seymour Range (17°28'S 146°02'E), 10 km north of Innisfail.

a. 31 May 1999, 50 m alt. One adult was spotted 3 m above the ground on the frond of a tree fern; on shaking the trunk of the fern to retrieve the skink it quickly jumped to the ground and was lost amongst ground debris.

b. 5 March 2000, 20 m alt. Two adults were seen- one was asleep in the groove of a *P. monticola* frond 0.6 m above the ground, the other was asleep on the leaf (as long as the skink itself) of a sapling approx. 1 m above ground. Both skinks were facing back towards the stem of the plants.

c. 21 October 2000, 100 m alt. An adult was seen 2.5 m up a small-leaved tree with head facing back towards the stem and the tail curled back around.

d. 21 Jan 2001, 20 m alt. An adult was seen 0.3 m above the ground on a leaf with head facing back towards the stem.

e. 28 May 2000, 20 m alt. An adult was seen asleep on the thin branch of a sapling 1.2 m above the ground.

3. Nandroya Falls circuit (17°36'S 145°45'30"E) top half, 350-450 m alt., Wooroonoran NP (Palmerston section), 10 km west of East Palmerston.

a. 18 July 1998. Approximately 20 individuals, mostly adults were observed asleep on fern fronds and low branches.

b. 20 April, 1999. More than a dozen adults were observed sleeping perched on the extremities of low vegetation (<1 m tall). In an approximately 2 m<sup>2</sup> area four individuals were located, three of these on the same sapling.

c. 6 October, 2001. A total of 23 skinks was located along the trail comprising two size classes (adults and small 'adults'). Four of the adults were females with developing eggs/ova, most skinks were orientated



towards the stem of the plant and all but two had their heads above or at the same elevation as the body. Ferns and broad leaf saplings were commonly selected plants. Skinks ranged in height from 0.15–1.0 m above the ground.

d. 27 October 2001. A total of 35 skinks (mostly adults) was located along the trail, most of these along the section bordering Douglas Creek (below Nandroya Falls). The majority were asleep on low ferns (<1 m) and the highest located individual was some 2 m above the ground.

e. 25 November 2001. A total of 40 skinks was located at heights from 0.3 m to 1.7 m on saplings and low ferns.

4. Disused logging trail (17°32'S 146°04'E), Moresby Range, 3 km east of Innisfail.

1 February 1999, 40 m alt. An adult was observed 0.8 m above the ground, asleep and perched on the leaf of a lantana vine.

5. Alice River, Eubeenangee Swamp NP (17°24'30"S 149°55'E), 13 km north-west of Innisfail.

5 February 2000, 10 m alt. An adult was observed 0.8 m above the ground asleep on the leaf of a sapling.

## DISCUSSION

The observations above indicate that *S. basiliscus* sometimes go to extreme lengths (literally!) to avoid sleeping on the ground. In several instances (described above) individuals were seen at heights more than 20 times their own total lengths! While this is perhaps not an unusual behaviour for arboreal species, it is for *S. basiliscus* since its does not possess the adaptations that characterise arboreal skinks (e.g., elongate limbs, toes etc.; Greer, 1989). Even excluding the more extreme instances observed, it is clear that the species habitually occupies a part of the habitat at night that it does not normally use during the day.

Several other lizard species inhabiting rainforests of the Wet Tropics region are known to

use arboreal sleep sites. Two agamids, Boyd's Forest Dragon *Hypsilurus boydii* and the Eastern Water Dragon *Physignathus lesueurii lesueurii*, are frequently observed perched asleep on the terminal branches of vegetation at night (Anthony & Telford, 1996; Torr, 1997; pers.obs.). Both dragons are mainly arboreal, possessing adaptations for this mode of life and are (partly) terrestrial by day (Greer, 1989; Ehmann, 1992; Torr, 1997; pers.obs.). A single observation exists of arboreal behaviour in the fossorial skink *Glaphyromorphus fuscicaudis* in which an individual was located 2 m up a tree (Torr & Brown, 1991), though the circumstances of the find were not described. We have not observed the behaviour in similar-sized diurnal skinks that occur in sympatry with *S. basiliscus*, namely *Carlia rubrigularis* and *Lampropholis coggeri*, both of which appear to sleep beneath ground cover.

These observations would indicate the existence of a compelling reason(s) for sleeping above the ground at night. Sleeping above the ground may give lizards considerable protection from nocturnal predators. The stems of saplings are particularly sensitive to movement and may provide skinks with an 'early warning' of attacks. Snakes would appear the most likely predators of many lizard species in the Wet Tropics, in particular the Brown Tree Snake *Boiga irregularis*, Slaty Grey Snake *Stegonotus cucullatus* and the Eastern Small-eyed Snake *Cryptophis nigrescens*. These species are all nocturnal (*S. cucullatus* is also diurnal) and are known to feed on lizards (Greer, 1997: 117, 209). One of these species, *B. irregularis*, was observed consuming a *P. I. lesueurii* in its arboreal sleep site (Retallick & Hero, 1994). There may be other explanations for *S. basiliscus* sleeping above the ground: One alternative might be that the behaviour is an adaptation to avoid being flooded out of ground retreats at night. Frequent unpredictable and heavy localised rainfall in the Wet Tropics region leads to drenching of the ground layer and to flooding of watercourses and this may render conditions unsuitable to skinks at ground level. In

support of this explanation is the commonness with which *S. basiliscus* were observed sleeping on vegetation beside watercourses as opposed to higher ground and also the observation that the highest counts of lizards occupying arboreal perches occurred at beginning and end of the wet season (Anthony, 1996, 1997, 1999).

The tendency for *S. basiliscus* to orientate itself on leaves with the head pointing back towards the stem is curious and the reason for this behaviour is unknown. It has also been observed in *H. boydii* hatchlings (Torr, 1997), sub-adults and some adults (pers. obs.). Given the tendency for terminal branches and leaves to be flexible and bend under the lizard's own weight, such a posture would ensure that the head is always above, or at least level, with the body. Hence the posture may simply reflect what is most comfortable for the lizard. It may also help to channel water away from the lizard's head during heavy rain, when drops are running down the branches and leaves.

## ACKNOWLEDGMENTS

We thank the referees for their constructive comments and improvements to the manuscript.

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Figure 1: Two adult *Saprosaurus basiliscus* lying *in situ* on leaves: (a) at a distance and (b) close-up.





# AN OBSERVATION OF PREDATION OF A METAMORPH COMMON EASTERN FROGLET (*CRINIA SIGNIFERA*) BY THE PLAGUE MINNOW (*GAMBUSIA HOLBROOKI*)

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Introduced fish species in Australia have been implicated in the decline of several anuran species, including threatened species (Watson *et al.*, 1991; Morgan & Buttemer, 1996; Pyke & White, 1996; Gillespie & Hines, 1999). Of the twenty or so fish species that have been introduced to Australian waters, the Plague Minnow (*Gambusia holbrooki*) has so far received the most scrutiny regarding its potential impact upon Australian frog populations (Gillespie & Hero, 1999). Many Australian studies to date have demonstrated that *Gambusia* are capable of killing a variety of tadpole species (Harris, 1995; Reynolds, 1995; Morgan & Buttemer, 1996; Webb & Joss, 1997) and eggs (Reynolds, 1995; Pyke & White, 2000). However, *Gambusia* cannot consume large prey as these small fish are gape-limited predators (Gillespie & Hero, 1999), and they have not previously been reported to prey on metamorph or adult frogs. I report here on *Gambusia* preying upon a metamorph of the Common Eastern Froglet (*Crinia signifera*).

During May 1996 I visited associates on the far-north coast of NSW (Alstonville, 28°10'S, 153°21'E) who had collected a number of anuran larvae from a drying pond in a local park some days earlier. The larvae were at varying stages of development and included individuals of the Eastern Dwarf Tree Frog (*Litoria fallax*), Dainty Tree Frog (*Litoria gracilentia*) and Common Eastern Froglet.

A decision was made to release a small number of metamorphs into the garden pond. A metamorph of the Common Eastern Froglet (approximately 6 mm SVL) was placed on the edge of a pond amongst fringing vegetation. Upon release the frog entered the

water almost immediately. The frog had commenced swimming across the pond when it was set upon by a single mature *Gambusia*. It was seized it by the right arm and dragged into deeper water (approximately 35 cm), where numerous other *Gambusia* joined the attack. The *Gambusia* nipped at the limbs of the frog for several minutes, at which point it became apparent that the frog had been immobilised. The metamorph was then consumed gradually as tiny pieces of flesh were removed. Such behaviour parallels the tail-nipping behaviour observed when *Gambusia* prey on free swimming anuran larvae (Komak & Crossland, 2000) and fin nipping when *Gambusia* prey on larger fish (Myers, 1965).

This observation suggests that in addition to preying on aquatic life history stages of native anurans (Komak & Crossland, 2000), *Gambusia* are also capable of attacking and killing metamorphs of at least the smaller Australian anuran species. Although individual *Gambusia* are unable to consume prey of this size individually, they may cooperate to subdue larger prey in some circumstances.

The fact that predation of metamorphs has not previously been reported suggests that it may be a very rare event. In this case there were a large number of fish in a small pond, which supported an apparently meagre aquatic fauna (i.e. no anuran larvae, few aquatic invertebrates); suggesting that alternative prey were an influence on foraging behaviour.

## ACKNOWLEDGMENTS

I thank Dr. Arthur White and one anonymous referee for their comments on the draft manuscript.

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# RECORD OF A GIANT CARPET PYTHON, *MORELIA SPILOTA*, FROM THE MID-NORTH COAST OF NSW

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## INTRODUCTION

Reliable and corroborated data on the maximal size attained by Australian pythonid snakes is scarce (Greer, 1997). The longest and heaviest free-ranging snakes recorded in Australia are all Scrub Pythons (*Morelia amethistina*) with weights ranging from 19-25.9 kg (Anon, 1966; Fearn & Sambono, 2000; Fearn, 2002).

Carpet Pythons (*Morelia spilota*) are known to attain total lengths in the wild of 4200 mm (D. Munday in Fearn *et al.*, 2001). No weight data exists for outsize specimens and the heaviest recorded in the literature are 7 kg (Shine & Fitzgerald, 1995), 7.2 kg (Greer, 1997) and 11 kg (Fearn *et al.*, 2001).

In March 2002 the author collected data from a giant free ranging female Carpet Python from the Mid-North Coast of New South Wales.

On 4 March 2002 the wild caught *M. spilota* was brought to a meeting of the North Coast Herpetology Group (NCHG) to have its dimensions recorded. Over 70 people who were in attendance on that night witnessed the preliminary measurements.

The snake had been captured by the manager of a large rural property west of Port Macquarie on the NSW Mid North Coast (grid references will not be given for the exact site). The snake was brought to a NCHG member who convinced the property manager that its dimensions should be recorded. This was agreed to upon the condition that the snake be returned to the same property after the data was recorded.

Upon first inspection, the most impressive features of this python were its massive girth and head size (Figs. 1, 2). The author, with

the assistance of several other NCHG members, collected data on the dimensions of this snake, which are presented in Table 1.

## METHODS

Preliminary measurements were taken on 4 March 2002 and double-checked and recorded on 10 March 2002, three days after the snake had defecated. Snout-vent length (SVL) and total length were determined by placing the snake on the floor and running a flexible measuring tape along its spine. The mid body girth was also obtained by using a flexible measuring tape. Head measurements were obtained with vernier callipers. The head length was measured along the lower jaw and the head width was measured at the widest section of the skull behind the eyes.

Since the weight was the most outstanding measurement recorded, care was taken in ensuring the accuracy of the scales. The weight was double checked on 'Allflex' digital scales at a veterinary clinic. The bag containing the snake was placed on the platform of the scales which measured the weight to the nearest 100 g with an accuracy of  $\pm 1\%$ .

The snake was then removed from the bag and the bag alone was weighed. The 1.6 kg bag weight was subtracted from the total weight.

Sex was determined by using a sexing probe.

Three members of the NCHG who are experienced breeders of *M. spilota* examined the snake and each of them determined that the female was not gravid.

Six days after data collection the snake was released beside a creek gully where the property manager had seen the snake basking on several previous occasions.

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**Table 1. Measurements (mm) and mass (kg) of large sized female *Morelia spilota* from Port Macquarie, New South Wales.**

SVL	3020
Tail length	450
Total length	3470
Mid-body girth	410
Head length (along lower jaw)	79
Head width (at base of skull)	67
Mass	22.3

### DISCUSSION

I believe this is the heaviest *Morelia spilota* ever reliably recorded in Australia and the third heaviest free ranging snake recorded anywhere in Australia. While the scrub python (*Morelia amethystina*) is Australia's longest snake (Shine, 1994), the data presented here

indicate that some specimens of *M. spilota* can rival *M. amethystina* in mass. The only other Australian pythons likely to rival either of these two taxa are the olive pythons (*Liasis o. olivaceus* and *L. o. barroni*) (Barker & Barker, 1994).

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**Figure 1. The head of the *Morelia spilota***





**Figure 2. The python's massive girth and head size.**



### ACKNOWLEDGMENTS

I thank Michael Toohey, Jamie Stuart, Sam Power, Lionel Hollis and Henry Turnbull for assisting in the measuring of this large snake, and the 70+ members of the NCHG who can verify these measurements. Thank you as well to Cheyne Flanagan and Simon Fearn for checking a draft manuscript and to Kim Hollis and Sue Emerton for the photographs.

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# REPTILES INHABITING THREE MALLEE REMNANTS IN CENTRAL NEW SOUTH WALES

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## ABSTRACT

Pitfall trapping was used to sample the reptile fauna of three mallee remnants in central New South Wales. These remnants comprised one relatively large block, Pulletop Nature Reserve, and two linear remnants of differing width. Sampling occurred at the remnant edge and centre, and a range of habitat variables were measured at each trapping location. Fourteen species of reptile were trapped overall. Species richness and species abundance declined with decreasing remnant width, with a dichotomy between the large block and the linear remnants. There was a positive significant correlation between species richness and ground cover diversity and a negative significant correlation between species richness and litter. It is concluded that linear remnants are of significant value to mallee reptiles.

## INTRODUCTION

The temperate woodlands of the wheat-sheep belt of New South Wales have been extensively cleared for agriculture. The remaining vegetation is highly fragmented, much of it existing as small linear patches along roads and between paddocks. The maintenance of biodiversity within such disrupted landscapes is problematic. The long-term survival of some species may be dependent upon their ability to persist within, and move between, patches of suitable habitat. Mallee communities occurring in central New South Wales are typical of the pattern of fragmentation described above, being subject to widespread clearing in the latter half of the last century. These mallee communities supported a diverse reptile community, with, for example, 36 species of lizard and snake being record-

ed from a relatively large intact area (Cogger, 1984). With land cleared for cropping supporting only a few species of mallee reptile (Rawlinson, 1981), the conservation of the mallee reptile community in many areas is dependent upon patches of retained vegetation.

A limited number of published Australian studies have considered the effect of habitat fragmentation on lizard species and communities (Kitchener *et al.*, 1980; Hadden & Westbrook, 1996; Smith *et al.*, 1996; Sarre, 1998). These studies have generally shown that the existence of a given lizard species within a remnant is closely linked to the presence of suitable habitat (Kitchener *et al.*, 1980; Smith *et al.*, 1996), but that factors such as remnant area and its degree of isolation may also be important (Smith *et al.*, 1996).

Linear strips of native vegetation were not included in the aforementioned studies. The aim of this study was to compare the reptile fauna of a wide and a narrow linear remnant with that of a relatively large block of mallee, the latter approximating the natural condition. In this way it was hoped that some indication would be gained as to the value linear remnants may have for mallee reptile conservation. However, a number of factors mean that the findings detailed below should be viewed as suggestive rather than definitive. These include the facts that only three sites were sampled from one area, the resultant data sets were small, and a number of environmental variables were not constant across all remnants.

## STUDY AREA

The study area is located some 40 km north of Griffith in central New South Wales



(34°08'S 146°05'E). The topography of the area is flat to undulating with low sand ridges separated by areas of heavier soil. Mallee predominates, though cypress pine (*Callitris glaucophylla*) - *belah* (*Casuarina cristata*) woodland, with which the mallee intergrades in places, is also present. The mallee overstorey is dominated by mallee eucalypts (*Eucalyptus socialis*, *E. dumosa*, *E. gracilis*, *E. foecunda*), with occasional pure stands of scrub pine (*Callitris verrucosa*) and broom-bush (*Melaleuca uncinata*). The composition and density of the shrub layer varies, with wallaby bush (*Beyeria opaca*) often dominating. The majority of the groundcover is provided by litter, with substantial areas of bare ground. Following a succession of good years native and introduced grasses may be common. A sparse cover of porcupine grass (*Triodia scariosa* subsp. *scariosa*) may be present on the sandier sites. The average annual rainfall is around 400 mm.

## MATERIALS AND METHODS

Three sites were selected for investigation - an 80 m wide strip and a 20 m wide strip (hereafter referred to as the wide strip and the narrow strip respectively) and Pulletop Nature Reserve, a 145 ha remnant managed by the New South Wales National Parks and Wildlife Service. Pulletop Nature Reserve had not been burnt for some sixty years prior to this study and the linear remnants are thought to have experienced a similar fire regime. The three remnants differed in the time since they were isolated. They formed part of a network of linear strips and small patches of vegetation throughout the area, broken variously by formed dirt roads and farm tracks. The linear remnants were located approximately 2 km from Pulletop Nature Reserve and were themselves separated by a distance of approximately 1 km.

At each of the three study sites, two sets of pitfall traps were established. Each set comprised two traplines, a trapline at the remnant edge and a parallel trapline at the remnant centre (in the case of Pulletop Nature Reserve,

the remnant centre was taken as being 250 m from the reserve edge). Each trapline comprised two rows of pitfalls separated by a distance of 10 m. Each row comprised three pitfall traps (10 litre metal buckets) placed 5 m apart and linked by black plastic drift fence 15 cm high (after Caughley, 1985). The overstorey at all traplines was uniform, comprising mallee eucalypts. The understorey varied somewhat between traplines, principally with regards the density of the shrub layer, dominated by *Beyeria opaca* in all cases, and the presence/absence of porcupine grass. Slight differences in soil texture between sites are likely to be responsible for these differences in understorey. Traplines within the wide and narrow strips were open to grazing by domestic stock whilst those within Pulletop Nature Reserve were not. Traps were open for 12 days and nights in February 1985 and for seven days and nights in July 1985. Trapping results from July 1985 are not reported on further as only four individuals from a single species, *Morethia boulengeri*, were captured during this period.

An assessment of existing habitat was made for each trapline, with the exception of the narrow strip where the assessment was made for each set of traplines. Habitat variables recorded were mean litter ( $\text{g/m}^2$ ), mean shade (percentage shade), and ground cover diversity. The latter was calculated according to the information theory formula  $H = -\sum p_i \log_e p_i$  (Pianka, 1966), where  $p_i$  is the proportion of each of six ground cover categories (timber, grasses and other herbaceous ground cover, bare ground, porcupine grass, litter, other).

The small sample sizes meant that no statistical analysis of the results, as they relate to the influence of remnant width or edge effects, was attempted. Correlations between measured habitat variables with species richness, total species abundance and, for those species with greater than 20 records, individual species abundance were investigated. Relatively large mobile species (*Pogona barbata*, *Tiliqua occipitalis*, *Pseudonaja tex-*

*tilis*, *Varanus gouldii*) were excluded from these analyses. These species were considered to be largely independent of the microhabitat features being measured. Note also that for these analyses each set of traplines within the narrow strip were considered to be a single data point. Summed values obtained for species richness and abundance for these sites were halved, given that twice the trapping effort, relative to other sites, had been employed.

## RESULTS

Fourteen species of reptiles were trapped overall (Table 1). Two species were considered abundant (>20 captures), two were common (>10 captures), one was uncommon (5 captures), and nine were rare (< 5 captures). Table 1 shows total captures for all species for each site.

The mean number of species recorded from traplines within each site declined with decreasing remnant width (Figure 1). There is a dichotomy in species richness between Pulletop and the linear remnants. Trapline location did not appear to exert any influence over mean species number, and there was no apparent interaction between remnant width and trapline location. The mean number of captures per trapline for each locality declined with decreasing remnant width (Figure 2). This decline is marked when comparing Pulletop with the narrow strip but much less so in all other comparisons. Trapline location did not appear to influence the mean number of captures, and there was no apparent interaction between remnant width and trapline location.

A significant positive correlation was found between species richness and ground cover diversity ( $r = 0.680$ ,  $p = 0.030$ ), whilst species richness and litter quantity were negatively correlated ( $r = 0.663$ ,  $p = 0.037$ ). Ground cover diversity and litter quantity were themselves negatively correlated ( $r = 0.706$ ,  $p = 0.023$ ). No significant correlation ( $p < 0.05$ ) was found between species richness and shade, between species abundance

and any of the measured habitat variables, or between *Lerista muelleri* and *Lerista punctatovittata* and any of the measured habitat variables. Ground cover diversity declined with decreasing remnant width though the differences were not marked. Litter quantity increased with declining remnant width, but again the differences were not marked.

## DISCUSSION

Nine reptile species were recorded from the two linear remnants sampled, indicating they have value as reptile habitat. Given that suitable habitat for eight of these nine species is not provided within the surrounding matrix of croplands (Rawlinson, 1981), the value of such remnants to reptiles generally is significant. Of particular interest from a conservation perspective, however, is the richness and composition of reptile communities persisting in linear remnants relative to those that existed prior to fragmentation. Twelve species of reptile were recorded from Pulletop Nature Reserve, a relatively large intact block of mallee. This is twice the number recorded from either of the linear remnants. As well, a trend of declining species richness with decreasing remnant width was also apparent. These patterns are suggestive of a loss of species from linear remnants following fragmentation.

There is a large body of literature dealing with the impacts of habitat fragmentation upon biodiversity and the mechanisms by which such impacts occur (see Debenski & Holt, 2000, for an overview). The modest nature of this study does not allow for conclusions to be drawn as to whether such mechanisms may be operating in this instance. There are, however, a number of other factors that may have contributed to the observed patterns. These include sampling biases, microhabitat differences and variations in grazing regimes between sites.

It is possible that differences between sites in terms of species richness and total abundance may have been a result of sampling biases, with the area sampled potentially



declining with decreasing remnant width. Wide-ranging species would be especially vulnerable to such biases. Whilst there is little available information on the home range size and ranging behaviour of many Australian reptiles, the majority of the species recorded in this study could be expected to have small home ranges. A number of species recorded (*Pogona barbata*, *Tiliqua occipitalis*, *Pseudonaja textilis*, *Varanus gouldii*) are likely to range over large areas (Heatwole, 1976; Heatwole & Taylor, 1987). With the exception of *T. occipitalis*, these species are generalists. As such, they are able to make use of the matrix and could be expected to occur within small remnants (Rawlinson, 1981; Cogger 1989; Smith *et al.*, 1996). That three of these four species were recorded from the linear remnants supports this fact. It remains possible, however, that a number of rare mobile species that potentially occur within the study area, and which are reliant upon intact native vegetation, may have been undersampled in the linear remnants.

Whilst overstorey composition and structure was able to be controlled for between sites this was less readily achieved with regards the understorey and ground cover. Groundcover, in particular, is likely to be an important determinant of the presence or absence of the small, terrestrial reptile species that are most efficiently sampled by pitfall trapping. Areas with a high ground cover diversity are likely to provide a greater variety of microhabitats and so accommodate a greater number of species than more homogeneous areas (Pianka, 1971). An important contributor to ground cover diversity was the presence of porcupine grass. Numerous authors have commented on the importance of porcupine grasses in increasing reptile species diversity and abundance in arid and semi-arid environments (Pianka, 1969a, 1969b; Cogger, 1974, 1984). Ground cover diversity explained a substantial proportion of the variation observed in species richness between traplines, with species richness increasing with increased ground cover diversity. Mean ground cover diversity of traplines at each site

declined with decreasing remnant width and it is probable that a component of the variation between sites, in terms of species richness, can be explained by microhabitat differences.

Whilst no grazing by domestic stock occurred within Pulletop, the linear remnants were open to grazing by sheep. Stock tended, however, to forage in the open paddock areas, using the remnants more for shelter, and did not appear to have significantly impacted upon the understorey in these remnants (*pers. obs.*). The use of the remnants by sheep will cause compaction of the soil surface and the trampling of features such as burrows, actions which may potentially disadvantage fossorial species or species relying on burrows. For the two such species recorded in sufficient numbers to allow some consideration of these impacts, *Lerista punctatovittata* and *Lerista muelleri*, the results were equivocal. Overall, *L. punctatovittata* was more abundant within the grazed remnants whilst the opposite was true for *L. muelleri*.

A number of points are worth noting in regard to the relationship between microhabitat features and the occurrence of particular lizard species. *Ctenotus schomburgkii* was relatively common within Pulletop Nature Reserve, rare within the wide strip and absent from the narrow strip. This species is known to have a close association with porcupine grass and the general absence of this grass from sites within the linear remnants may explain the observed patterns (Cogger, 1983, 1984; Sadlier, 1987). *L. punctatovittata* was, overall, three to four times more abundant within the linear remnants compared to Pulletop Nature Reserve. Being fossorial (Cogger, 1989), one would expect *L. punctatovittata* to be advantaged by the higher levels of litter found within the linear remnants. As well, *L. punctatovittata* is a generalist species that has been shown to persist in cleared mallee areas (Cogger, 1989) and as such one would not expect it to be sensitive to fragmentation. The ecology of *L. muelleri* is

thought to be similar to that of *L. punctatovit-tata* (Cogger, 1989). Accordingly, one might similarly expect it to benefit from conditions existing within the linear remnants relative to Pulletp Nature Reserve. This was not the case, with this species being abundant within Pulletp Nature Reserve and uncommon within the linear remnants. This species was observed foraging throughout daylight in a variety of microhabitats, favouring the loose soil and debris associated with fallen timber but also occurring within clumps of porcupine grass. These observations help 'explain' the observed patterns of abundance, sandier soils and porcupine grass being associated with the Pulletp Nature Reserve traplines. *Morethia boulengeri* is a small, active skink often observed scuttling through the leaf litter or basking atop fallen timber. Fallen timber sufficiently decayed so as to contain cracks and hollows of sufficient size for lizards to gain entry are important to this species. Such timber provides basking sites, refuge from predators and may also be used for over-night or over-winter shelter. The species was present in low numbers across all sites, reflecting the widespread presence of required microhabitat features.

## ACKNOWLEDGMENTS

This project was originally suggested by John Brickhill, who also assisted with fieldwork. Judy Caughley imparted valuable field experience and helped focus the work undertaken. Don Driscoll and Hal Cogger reviewed an early draft manuscript and provided helpful comments. The NSW National Parks and Wildlife Service gave permission to work in Pulletp Nature Reserve. A special thank you to Doug Heath, The Acres, who allowed access to his property. I am grateful to my parents for supporting the project and to Peter Cameron, Rod Cameron and Albert Zampieri for assistance with field work.

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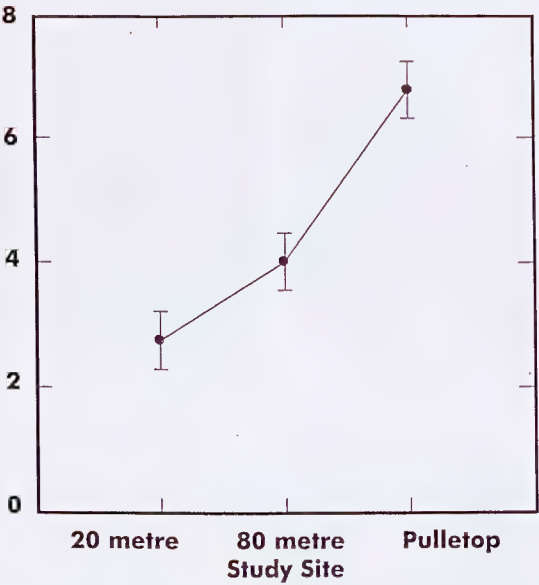
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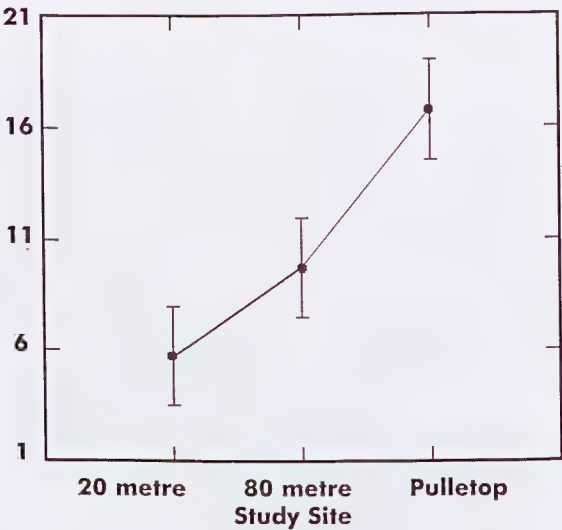
**Table 1. Number of captures for the different species of reptiles at each site.**

Species	20 m	80 m	Pulletop
<i>Pogona barbata</i> (Bearded Dragon)			2
<i>Amphibolurus nobbi</i> (Nobbi Dragon)			1
<i>Ctenotus robustus</i>			5
<i>Ctenotus schomburgkii</i>		2	11
<i>Lerista muelleri</i>	6	10	30
<i>Lerista punctatovittata</i>	12	16	4
<i>Menetia greyii</i>		2	
<i>Morethia</i> sp.			2
<i>Morethia boulengeri</i>	2	7	6
<i>Tiliqua occipitalis</i> (Western Blue-Tongued Lizard)		1	
<i>Diplodactylus vittatus</i> (Wood Gecko)			1
<i>Diplodactylus intermedius</i> (Eastern Spiny-Tailed Gecko)	1		1
<i>Varanus gouldii</i> (Gould's Goanna)	1		3
<i>Pseudonaja textilis</i> (Eastern Brown Snake)	1		1
<b>Total species</b>	<b>6</b>	<b>6</b>	<b>12</b>
<b>Total individuals</b>	<b>23</b>	<b>38</b>	<b>67</b>

**Figure 1.** Mean number of species of reptiles recorded from traplines within remnants of different widths. Confidence intervals are one standard error.



**Figure 2.** Mean number of captures of reptiles from traplines within remnants of different widths. Confidence intervals are one standard error.





## DOES *TYMPANOCRYPTIS LINEATA* OCCUR IN NEW SOUTH WALES?

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Smith *et al.* (1999) recently provided genetic and morphological evidence that *Tympanocryptis pinguicolla*, formerly regarded as a subspecies of *T. lineata*, warrants full species status. They also considered the status of other south-eastern Australian populations variably ascribed to *T. lineata* and *T. tetraporophora*. They concluded that *T. tetraporophora* was genetically distinct from *T. lineata*, but that morphologically it could only be differentiated from *T. lineata* by the presence of a pair of femoral pores in addition to the single pair of preanal pores present in both species. Although their genetic sampling from New South Wales other than for *T. pinguicolla* was limited to two individuals from Lightning Ridge, both of which were genotyped as *T. tetraporophora*, they used the single morphological criterion of femoral pores to recognise both *T. tetraporophora* and *T. lineata* from northern and north-western New South Wales (their list of specimens examined includes additional records not included on their distribution map). This conclusion is generally compatible with previously published distribution maps for *T. tetraporophora* and *T. lineata* in New South Wales, which suggest that both species have a broad distribution west of the Great Dividing Range (Wilson & Knowles, 1988; Ehmann, 1992; Cogger, 2000), although Swan (1990) only recognised *T. lineata* and *T. intima* in this region.

In a separate study, Greer and Smith (1999) analysed a number of aspects of morphology and reproductive biology of *T. tetraporophora*, based on material in the Australian Museum and the Queensland Museum. As part of that study, Greer examined all *Tympanocryptis* in the Australian Museum collection,

and consistently found femoral pores in all New South Wales material previously identified as *T. lineata* (exclusive of *T. pinguicolla*), *T. tetraporophora* and *T. intima*, although this finding was not reported at the time (A. Greer, pers. comm.). The distribution map for *T. tetraporophora* published by Greer and Smith (1999) includes this material. The material examined by Greer and Smith (1999) and identified by Greer as *T. tetraporophora* included all eight New South Wales specimens identified as *T. lineata* by Smith *et al.* (1999). To resolve this discrepancy, I re-examined all of these contentious specimens (Australian Museum R47292, R52926, R70095, R127122, R127124, R134597, R138756, R138799). Seven are females and one a juvenile male, and all have pores much smaller than in adult males from the same or nearby localities. In all cases, femoral pores are present, of similar size to the preanal pores or a little smaller, and in some cases only discernable when examined under a dissecting microscope. Mitchell (1948) had previously warned about the need to examine females closely to locate pores.

Hence, I reidentify all eight specimens as *T. tetraporophora* and conclude that as yet there is no evidence that *T. lineata* occurs in New South Wales. However, Hutchinson (1998) has identified *T. lineata* from the adjacent parts of South Australia, raising the possibility that the species may occur in the poorly-collected south-west of New South Wales. Given the need for careful examination to discern the small preanal and femoral pores in females and juvenile *Tympanocryptis*, any claims for the occurrence of *T. lineata* from New South Wales should be supported by

voucher specimens sexed by examination of gonads, and should preferably include adult males with obvious pores.

I further note that these misidentified *T. tetraporophora* individuals account for over a third of the *T. lineata* sample used by Smith *et al.* (1999) for their multivariate morphological analyses, and recommend that their morphological conclusions be treated as tentative.

#### ACKNOWLEDGMENTS

I thank A Greer for discussion of the problem, permission to present his unpublished findings, and comments on the manuscript. R. Sadler and W. Osborne also read the manuscript.

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# CAPTIVE REPRODUCTION OF THE INLAND CARPET PYTHON (*MORELIA SPILOTA METCALFEI*)

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## INTRODUCTION

Captive studies remain the richest source of published data relating to the reproductive biology of Australian pythons (Greer, 1997). Specifically, captive studies have provided excellent baseline information on a myriad of life history characteristics (including reproductive cycles, gestation periods, offspring size and growth) for a range of species that are otherwise little studied (Barker & Barker, 1994; Greer, 1997). In this article, captive reproduction of the Inland Carpet Python (*Morelia spilota metcalfei*) is described.

The Inland Carpet Python is a moderately large (to 3 m total length) member of the *Morelia spilota* species complex, found across inland regions of south-eastern Australia (Greer, 1997). Present descriptions of the sub-species taxonomy, distribution and ecology are poor, being largely restricted to a range of sporadic observations (see Webb & Rose, 1984; Wells & Wellington, 1984, 1985; Brooker & Wombey, 1986; Schwaner *et al.*, 1988; Wilson & Knowles, 1988; Robertson *et al.*, 1989; Coventry & Robertson, 1991; Morris, 1993; Barker & Barker, 1994; Sadler, 1994; Shine, 1994; Annable, 1995; Greer, 1997). Published descriptions of reproduction are limited to observations upon a single captive breeding (B. Barnett cited in Barker & Barker, 1994). This paper provides a further record of captive reproduction for *M. s. metcalfei* and presents new data on aspects of reproductive chronology.

## MATERIALS AND METHODS

### Specimens

Both animals used in this study were long-term captives in excess of 150 cm total length at the time of reproduction. The male (Inland Carpet

Python No.1 - ICP1) was approximately six years of age having been purchased as a young, wild-caught adult in March 1995 (Heard, 1999). The female (ICP2) hatched in February 1996 and reached sexual maturity at approximately two years of age. The specific geographic origin of both adult specimens is unknown; however, both resemble specimens from southern sections of the Murray River drainage (pers. obs.).

This pair reproduced twice between 1998 and 2000; however, detailed observations were recorded during the second season only. Data from this latter season are presented below. Observations from the previous season will be added where appropriate.

### Housing

The facilities used to house both adults were of fairly standard design. Specimens were kept separately in a large cabinet containing two identical cages (vertically arranged) measuring 405 mm wide by 915 mm long by 410 mm high. Melamine-coated chipboard (16 mm) was used throughout. Frontal access was provided by sliding glass doors in each case, offering clear viewing and accessibility for cage maintenance. Cage decorations were kept relatively simple, consisting of a substrate of pre-washed aquarium gravel, climbing branches (mounted at least 30 cm above the substrate) and a small plastic water bowl. Plastic boxes with suitably sized entrance holes were used as hide areas for both adult animals.

Heating was supplied during daylight hours only and consisted of one incandescent light bulb per cage, controlled by a central rheostat. Each bulb was suspended above a large, flat piece of granite to provide a single basking site. For ICP2, a 40 W reflector globe was used. A standard 40 W incandescent bulb proved suffi-

cient for ICP1 who received some floor heating from the cage below. Background temperature (including nightly lows) fluctuated with room temperature; however, basking sites also served as heat sinks for nocturnal thermoregulation (see Fearn, 1996). Photoperiod followed a Melbourne cycle and utilised a dawn/dusk system described by Kortlang (1991). Under this regime, cage photoperiod is slightly shorter than room photoperiod to produce a dawn/dusk effect. Room lighting was provided by a fluorescent light holding two 18 W 'White Tubes' mounted on the room ceiling approximately 1.5 m from the cages themselves. No natural daylight entered this room, and thus, specimens were reliant solely upon the photoperiod manipulations described above.

### Husbandry Pattern

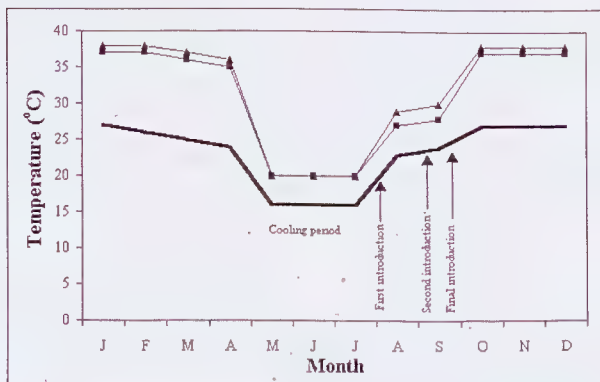
The temperature regimes provided were intended to reflect daily and seasonal fluctuations experienced in the field. The seasonal pattern of heating was typified by high temperatures from November to April, a cooling period between 1 May - 1 August, followed by a spring warming period ending in October

(Figure 1). Seasonal changes in ambient room temperatures were particularly important in facilitating these fluctuations. The lack of heating during the night often allowed considerable temperature variation over a twenty-four hour period.

Feeding was also varied seasonally. Peak consumption occurred in the summer months and tapered off to complete cessation during the winter cooling period, following Field (1990). ICP1 regulated his own pattern, accepting food between November and April only. This specimen refused to feed on rats and was subsequently fed adult mice *ad libitum*. During the summer months, the female was fed thawed adult rats fortnightly.

On 3 August, 9 September and 26 September 1999 the male was placed in the female's cage and the subsequent interaction monitored for thirty minutes. The pair was monitored daily until the male was removed between four and five days later. Introduction periods were similar to those reported previously for captive specimens of this subspecies (Barker & Barker, 1994).

**Figure 1. Approximate temperature regimes supplied to both adult carpet pythons during the 1999/2000 season. Lines with symbols indicate daytime basking temperatures (squares - ICP1, triangles - ICP2). Nightly minimum air temperatures are indicated by the bold line.**





## Female Husbandry and Egg Incubation

Following introductions, ICP2 was monitored closely for signs of pregnancy. Following completion of a pre-laying slough the hide box was converted to a nest box by the addition of a layer of moist sphagnum moss (ca. 6 cm deep). Basking site temperatures were also increased to approximately 38°C, causing a slight increase in nest box temperatures during the day (to ca. 30°C).

Standard egg incubation techniques were used throughout (see Ross & Marzec, 1990; Barnett, 1998). The incubator used was constructed from 16 mm floor ply and measured 650 mm long by 425 mm wide by 855 mm high (following design of Weigel, 1988: 88). Heating was provided by five 40 W blue incandescent globes and controlled by a Landis and Gyr RAD 5 thermostat (operational temperature variance = 2°C). A large plastic incubation container was half filled with 200 g of large grade vermiculite (mixed with an equal weight of water) and pre-heated to the desired incubation temperature (32°C).

Eggs were removed from the female within eight hours of deposition and placed within pre-made depressions in the vermiculite substrate. Five eggs were weighed and measured shortly after removal from the nest box. Weights were recorded to the nearest 0.1 g using an AND Compact Digital Scale (HL series), while measurements were recorded with Mitutoyo Dial Calipers. Temperatures within the incubation container were monitored with a digital thermometer and generally varied between 30 - 32°C; however, high room temperatures resulted in maximums of 36°C being reached on several days late in the incubation period. Gaseous exchange was allowed by opening the container lid for several minutes each week.

## Hatchling Husbandry

Hatchlings were allowed to emerge from their eggs voluntarily, and then moved to separate housings. Each specimen was housed in a medium sized plastic tub ('Decor' variety with

a height of at least 15 cm), containing a paper substrate, climbing branches, a small water bowl and a hide area. These containers were either placed upon a Flexiwatt heat pad (controlled by a Thermofilm probe thermostat) or within the incubator, and heated to 31°C. Photoperiod matched that provided to the adults. All hatchlings were sprayed with warm water (c. 25°C) on a daily basis until completion of the post-hatching slough. First meals were offered at one month of age and consisted of thawed fuzzy mice (ca. 5.0 g). All meals were offered in the early evening under torchlight (to minimise disturbance) and provided once every three weeks.

Hatchlings were measured for total length and weight at birth, and monthly for three months (February - April). Weights were again measured to an accuracy of 0.1 g using the above-mentioned scales. To avoid potential damage to hatchlings, total length was measured by immobilising each snake under clear Perspex and tracing the body midline. Time restrictions during January 2000 allowed only hatchlings one to five to be measured at birth.

## RESULTS

### Breeding Observations

Both adult specimens remained largely inactive during May and June, spending the majority of time concealed within their respective hide areas. Activity increased slightly in July when occasional basking and nocturnal activity was observed. The first introduction on 3 August was uneventful with no immediate courtship or mating activity. Both snakes showed little interest in the others presence. During the re-introduction periods (9 September, 26 September) the pythons remained concealed together within the hide area almost continuously. A possible mating was noted on 26 September (tails entwined); however, visibility was poor and the event could not be confirmed.

On 9 October the female was noted to be displaying 'belly up' posturing and a pre-

laying shed was recorded on 30 October. During this time, feeding progressed normally and long periods were spent basking on the granite rock provided. This often continued into the evening, up to five hours after the reflector globe was extinguished. Throughout November, ICP2 spent long periods preparing the nest box. Inspection revealed a chamber had been created within, primarily by pushing the majority of sphagnum moss to one side, walling off the left-hand side of the box. Egg deposition ( $n = 20$ ) occurred in the early hours of 26 November 1999 within this chamber. Upon discovery, the female was coiled around an adherent clump of 15 eggs and was displaying shivering thermogenesis (well spaced, rhythmic contractions). The remaining five eggs lay singly on the nest box floor. The pre-laying slough occurred twenty-six days before egg deposition, while a post-laying slough was completed twenty one days later, on 17 December.

## Eggs

All eggs were a uniform ivory white coloration and appeared healthy, turgid specimens. For the five eggs measured at oviposition, length and mass varied little (Length: mean =  $51.2 \pm 0.3$  mm; Weight: mean =  $39.9 \pm 0.5$  g). Egg diameter was

more variable (mean =  $42.2 \pm 2.5$  mm) (Table 1).

All eggs proved fertile and hatched without incident. In the latter stages of incubation the majority of eggs appeared somewhat deflated; however, a mean weight gain of 5.3 g was recorded from the five eggs monitored during this period. Incubation spanned sixty-one days (26 November - 27 January).

## Hatchlings

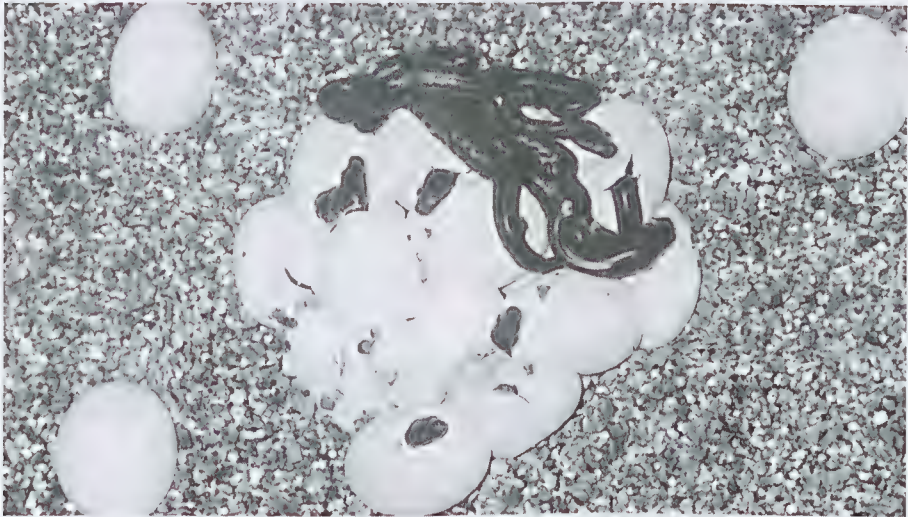
Neonates emerged between 27 - 30 January 2000 (Figure 2). Most individuals remained within the egg for up to two days following pipping (slitting of the egg casing and protrusion of the head). All animals displayed a dorsal pattern with a dull black basal color, interrupted by grey bars and blotches. Ventral scutes were grey with black flecks. On average, a post-hatching slough occurred at 9 days (range 8-12 days). All neonates were sexed by probing revealing a clutch-sex ratio heavily skewed towards females at 1:3 (5M:15F). Upon completion of the post-hatching slough, nocturnal activity became intense. First meals were eagerly accepted by all hatchlings and each became a voracious feeder from this point onwards. All specimens were placid in disposition however, and would always attempt to flee upon provocation.

**Table 1. Morphometric data recorded from five eggs deposited on 26 November 1999 (PL = post-laying, PH = pre-hatching).**

Measurement	Length(mm)	Diameter(mm)	Weight(g) - PL	Weight(g) - PH
Range	50.0 - 51.6	36.1 - 51.5	38.6 - 41.2	42.8 - 47.5
Mean	51.2	42.2	39.9	45.2
SD	0.8	5.7	1.1	2.1
SE	0.3	2.5	0.5	0.9



**Figure 2.** Neonate *M. s. metcalfei* hatching on 28 January 2000. Note the black basal coloration of the dorsal pattern.



At birth, hatchling pythons ranged between 402 - 446 mm TL (mean =  $432.4 \pm 8.2$  mm) and 22.0 - 25.5 g in weight (mean =  $23.6 \pm 0.2$  g) (Table 2). Growth in length and weight showed some disparity. Length gain was greatest during February (mean = 41.3 mm)

and decreased steadily during the following months. However, weight gains were not recorded until March after an initial mean weight loss of 3.8 g. At three months of age, hatchlings had gained a mean of 103.5 mm TL and 11.6 g in weight.

**Table 2.** Growth of hatchling *M. s. metcalfei* between birth and three months of age.

Measurement	Sample Size	Range	Mean	SD	SE
<b>Total Length (mm)</b>					
Birth	5	446 - 402	432.4	18.3	8.2
February	20	489 - 453	473.7	10.5	2.3
March	20	531 - 496	512.6	10.8	2.4
April	20	559 - 520	535.9	11.6	2.6
<b>Weight (g)</b>					
Birth	20	25.5 - 22.0	23.6	0.8	0.2
February	20	20.9 - 18.9	19.8	0.6	0.1
March	20	29.8 - 25.2	27.8	1.1	0.2
April	20	36.3 - 27.9	31.3	2.3	0.5

## DISCUSSION

While incomplete, the data presented above describe the reproductive pattern of captive *M. s. metcalfei*, and allow comparison with that observed in other sub-species of carpet python, both in the field and captivity.

Two mating periods are apparent amongst Australian sub-species of carpet python; namely, late winter to early spring and mid to late spring (Greer, 1997). Sub-species inhabiting mesic, tropical localities (eg. *M. s. cheynei*, *M. s. variegata*), typically mate between July and September (Day, 1990; Kortlang, 1991; Barker & Barker, 1994). *Morelia spilota mcdowelli* may be loosely affiliated with this group (Leydon *et al.*, 1990; Shine & Fitzgerald, 1995). However, those sub-species living at more southerly latitudes generally court later in spring, as is evident from field studies on *M. s. spilota* (Slip & Shine, 1988). Copulation occurred between August and September in the captive specimens of *M. s. metcalfei* studied here. These dates match those documented previously (B. Barnett cited in Barker & Barker, 1994), but probably result from exposure to artificially high winter temperatures. In the wild state, mate pairing in *M. s. metcalfei* has been observed during mid to late spring (Shine & Fitzgerald, 1995; P. Robertson, pers. comm.; pers. obs.).

The gestation period (copulation to egg deposition) could not be calculated from the data presented here; however, was recorded at 75 days during the previous season. As with the pre-laying shed - oviposition interval, this period is consistent with other carpet pythons (Barker & Barker, 1994). Similarly, offspring characteristics including clutch size, egg incubation periods, egg morphometrics, egg fertility rate and hatchling length and mass conform with those recorded previously for *M. s. metcalfei*, and indeed those of all other carpet pythons (Barker & Barker, 1994; Greer, 1997). There appears little sub-specific variance in these characteristics.

Some interest has been expressed in neonate

colour pattern as a diagnostic aid in carpet python taxonomy (Greer, 1997). Greer alludes to a division between the sub-species based upon pattern definition and basal color, and again, it appears sub-species from the coastal north of the continent differ from those living in cooler climates. Current data suggest neonate *M. s. variegata* and *M. s. mcdowelli* typically display a uniform rich brown coloration following the first slough, while *M. s. bredli*, *M. s. imbricata*, *M. s. metcalfei* and *M. s. spilota* are darker at birth and develop the lighter pattern elements later in life. In the neonate *M. s. metcalfei* discussed here, the dorsal background colour was dark black, but developed lighter brown pattern elements during the first twelve months of growth. This would confirm that *M. s. metcalfei* aligns with the latter group, should such a division be valid. To test this contention, further information on the neonate pattern of *M. s. cheynei* is required (Greer, 1997). Current data are ambiguous and suggest neonate *M. s. cheynei* may be patterned in either contrasting black and greys, or a uniform brown coloration (Barker & Barker, 1994; B. Barnett pers. comm.). It may simply be the case that sub-specific variation in neonate colour pattern parallels that shown by adult specimens and thus tells us little more about the taxonomic relationships present within the complex.

Limited data on offspring growth are available from this study. Increases in total length were greatest during the initial month and analogous to a mean weight reduction of almost four grams. As no food was consumed during this period, it is assumed egg yolk remnants and/or fat stores were metabolised to produce this growth. In the field, neonate *M. s. metcalfei* are estimated to emerge in late February to early March (P. Robertson, pers. comm.) and as such, variation in these energy stores may be particularly relevant to hatchling survivorship over the winter months.

From the present data, the reproductive biology of *M. s. metcalfei* is similar to that described for other carpet pythons, particu-



larly those from higher latitudes. Nonetheless, data from wild specimens are required before generalisations can be made, particularly in relation to reproductive cycles. In the interim, priorities for captive studies include examining relative clutch mass, neonate pattern development, estimates of age to sexual maturity, courtship behaviour (particularly the presence/absence of male-male combat) and aspects of maternal incubation.

## ACKNOWLEDGMENTS

Thanks to Peter Robertson and Rob Valentic for critically reviewing an earlier draft of this manuscript. Peter also related his experiences with Victorian specimens of *M. s. metcalfei*. Special thanks to Jeremy Tscharke who cared for these specimens over two weeks in early January 2000. Brian Barnett provided advice on the captive maintenance and reproduction of carpet pythons and neonate colour patterns of *M. s. cheynei*.

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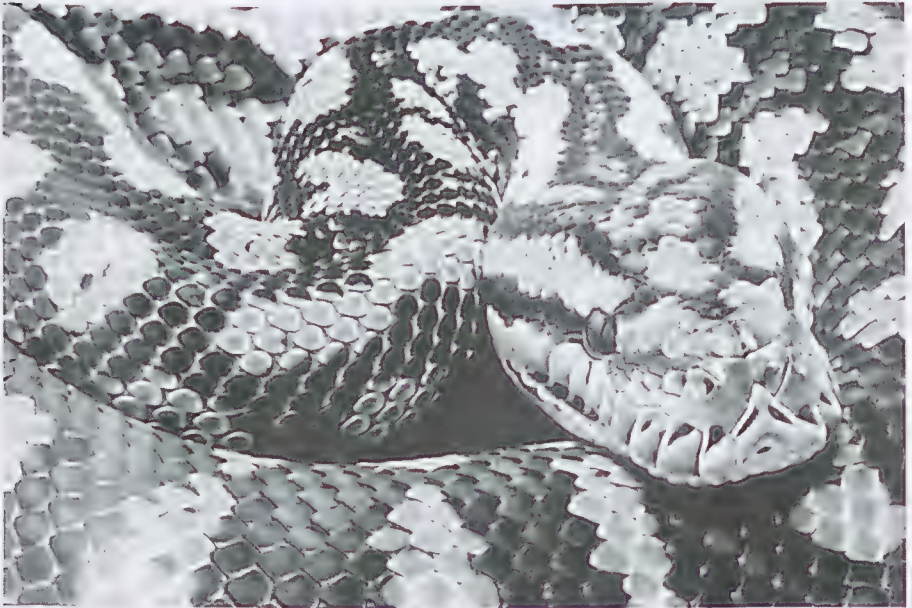
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**Figure 2. Female inland Carpet Python (*Morelia spilota metcalfei*)**



## CRYING IN THE DARK: PERSISTENT CALLING AT A DRY BREEDING SITE BY THE BLEATING TREE FROG, *LITORIA DENTATA*

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The Bleating Tree Frog, *Litoria dentata*, is an arboreal hyloid frog found through the coast and adjacent ranges of eastern Australia from south-eastern Queensland to the south coast of New South Wales (Cogger, 2000). The frog lays its clutches in both permanent and temporary still water sites, particularly large swamps, within a range of vegetated environments (Cogger, 2000). Calling occurs for only a few nights at a time following more moderate to heavy rainfall after which the adults presumably generally retreat to the tree tops as males can occasionally be heard calling there (pers. obs.).

Bleating Tree Frogs have been regularly recorded in the broad area since 1993 as part of ongoing monitoring of the breeding populations of frogs using stock and fire dams in and around Chaelundi State Forest, west of Coffs Harbour in mid-north coast New South Wales (see Lemckert and Morse, 1999). Surveys of frogs at breeding ponds were again undertaken during November of 2000 after some moderate to heavy rainfalls (at least 50 mm in the last 48 hours). Large numbers of frogs were recorded at all sites in Chaelundi State Forest including one pond that had five different species of frogs chorusing around it (Table 1). Bleating Tree Frogs were not present at this pond on this occasion, but had previously been recorded there (Table 1). The same pond, which had held water in all previous years, was found to be dry in February 2001, apparently due to a cracking of its base. It remained dry over a further three further visits including in November 2001, when a survey was again undertaken after moderate rainfall (at least 30 mm over the previous 48 hours). Despite the dry state of the pond, at least 200 Bleating Tree

Frogs were recorded chorusing around it. The males were calling both from the ground and from sedges growing in the dried pond area. No amplexing pairs were seen, but chorusing continued throughout the 12-minute survey period.

Prior to its drying out, I regularly recorded choruses of other frog species at this pond including Peron's Tree Frogs (*Litoria peronii*), Spotted Grass Frogs (*Limnodynastes tasmaniensis*) and Dusky Toadlets (*Uperoleia fusca*) as well as Bleating Tree Frogs (Table 1). At the November 2001 survey, no other species formed significant choruses at the site and were represented by only a couple of individuals. The presence of *Litoria dentata* did not cause the other species of frogs to leave the pond as other full ponds in the area maintained large numbers of all species, including *L. dentata*.

Why did the other species of frogs respond to the state of the pond but the Bleating Tree Frogs did not? The answer may be related to the breeding habits of the different species. The other species of frogs located in larger numbers at the pond prior to its drying out are consistent callers. That is, males are present continuously around the breeding pond during the spring to autumn breeding season and call on most nights, irrespective of the levels of recent rainfall (unpubl. data). These species may have already discovered the dry state of the pond and moved away. The Bleating Tree Frog has a similar length of breeding season, but is an "explosive" caller, congregating at the breeding site only after rainfall events (Barker et al., 1995). The rain immediately prior to the survey was the first substantial rainfall of spring in 2001 and so



the first breeding opportunity for the species in the 2001/2002 season. The pond had filled with water the previous spring/summer and, therefore, was probably the first time the male Bleating Tree Frogs had encountered the pond in its dry state. If this was the case, the males would probably have called whilst waiting for the rains to fill the pond as per usual and only later discovered that the pond did not fill with water. After the next heavy rainfall event, it would be expected that the majority of the males would attempt to find new sites and the number of Bleating Tree Frogs using the site would drop considerably. If possible, the site will be monitored after heavy rains in the area next season to see if this does actually happen.

A further interesting question is why were no Bleating Tree Frogs recorded at the site in November 2000. Bleating Tree Frogs were present at all other ponds in this survey period, usually in very large (50 to >200) numbers and were present at the site in December 1997 as well as in 2001 (Table 1). There is no clear answer to this question. Inter-specific exclusion does not seem possible (given the mixed choruses at other sites) and there is no reason to believe that the frogs would have not yet arrived to breed at the pond. This situation remains a mystery.

## ACKNOWLEDGMENTS

I would like to thank Maria Adams for her assistance during this survey and Tracey Brassil for her assistance in numerous previous surveys and to the anonymous reviewers for their comments on this manuscript. I also thank State Forests of NSW for their continued support of my research. The appropriate National Parks and Wildlife Service and Animal Ethics licenses were obtained for this field work.

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**Table 1. Species and numbers of frogs calling at the pond in December 1997 (full), November 2000 (full) and November 2001 (empty).**

Species of Frog	December 1997	November 2000	November 2001
<i>Adelotus brevis</i>	0	3	0
<i>Litoria chloris</i>	0	0	1
<i>Litoria dentata</i>	>50	0	200
<i>Litoria gracilentia</i>	0	0	1
<i>Litoria latopalmata</i>	0	1	0
<i>Litoria peronii</i>	20	20	2
<i>Limnodynastes peronii</i>	10	15	0
<i>Limnodynastes tasmaniensis</i>	10	5	0
<i>Mixophyes fasciolatus</i>	4	12	0
<i>Uperoleia fusca</i>	30	>50	3

# DIURNALITY AND BASKING IN THE PRICKLY FOREST SKINK *GNYPETOSCINCUS QUEENSLANDIAE*

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## INTRODUCTION

The Prickly Forest skink *Gnypetoscincus queenslandiae* is a distinctive, moderately large (SVL 80 mm), ovoviviparous, terrestrial lizard endemic to Wet Tropics region of north-eastern Qld where it occupies lowland and upland rainforest (Wilson & Knowles, 1988; Greer, 1989; Covacevich & McDonald, 1991; Cogger, 2000). The species has been the recent subject of ecological, morphological, demographic and evolutionary studies (Cunningham, 1993; Cunningham & Moritz, 1997; Schneider & Moritz, 1999; Sumner *et al.*, 1999). Despite this work, relatively little is known of the habits of this secretive skink as it is usually found beneath moist rotting logs during daytime searches (Greer, 1989; Cogger, 2000; pers. obs.). The species is generally regarded as nocturnal and cryptozoic (Cogger, 2000; Ehmann, 1992; Covacevich & McDonald, 1991; Wilson & Knowles, 1988; Frith & Frith, 1987). Greer (1989: 154) states: 'In living in tropical rainforest often in or under rotting logs and probably not emerging until after dark, if at all, *Gnypetoscincus queenslandiae* is one of the most ecologically buffered terrestrial reptiles in Australia'.

Recently however there have been several reports indicating that the species is active during the day. Anthony (1994; pers. obs.) observed two *G. queenslandiae* in the open, one was basking on a log in direct sunlight, the other was active in leaf litter (no sunlight). Valentic (1996) observed five specimens in the open during overcast daytime weather. All specimens were stationary and on top of leaf litter into which they retreated when disturbed. In this note we report on field observations of day activity in *G. queenslandiae*

that indicate partial emergence during daylight hours is quite common in the species. In addition, we describe observations of basking by gravid females.

## METHODS

*Gnypetoscincus queenslandiae* sightings were made along walking trails through rainforests in the Wet Tropics of north Queensland. Observations occurred incidentally over several years. While *G. queenslandiae* was not specifically targeted or searched for, terrestrial reptiles were. Latitudes and longitudes of particular locations were estimated (to the nearest 30'') from 1:50,000 topographic maps (Series R733 Mena Creek, Cooper Point, Bartle Frere, Rumula, Mt Spurgeon) and altitude was estimated to the nearest 50 m from topographic maps where the precise location was known. Temperatures quoted refer to those taken on site to the nearest 1°C.

## OBSERVATIONS

### General

Skinks were typically observed with the head and anterior body, propped up by the front legs, protruding from beneath cover. Skinks appeared alert, diverting their attention on occasion by slight head movements but were otherwise motionless. They were seen protruding from the ends and cavities of decaying stumps and logs, cavities that had formed in live tree trunks, crevices formed by exfoliating granite and occasionally from beneath basalt rocks resting on soil. Hollows that had formed in the ends of sawn logs beside walking trails were often utilised by skinks. They were commonly seen protruding from

the cut ends. On being disturbed the typical reaction of skinks was to retract the head/anterior body, turn around (inside the cavity) and move deeper into the cavity. With care, it was possible to approach within several metres of skinks, without them retreating. Skinks that retreated typically emerged in a matter of minutes. On 12 occasions, skinks that were spotted protruding from cavities were watched from a distance for a period of up to 15 minutes, but did not move (however see observation 5 below). On several occasions (e.g. observation 1) skinks were observed in the open and apparently active but only on overcast days.

*Gnypetoscincus queenslandiae* were not seen active at night, despite a considerable spotlighting effort (not specifically targeting the species). This may indicate that most nocturnal activity takes place beneath ground cover. Alternatively, it may reflect the difficulty in detecting this species in the open by spotlighting. On occasion we have located the species at night beneath ground cover, although ground cover searches were mostly conducted during the day.

Some of our observations are described below; all took place during the day (7am through to 6pm).

1. Mt Bartle Frere (eastern) summit trail (Start 17°26'S 145°51'30"E), Wooroonoran NP (Josephine Falls section), 30 km north-east of Innisfail.

a. 17 April 1998. 100-900 m alt. Completely overcast, 24-28°C. More than a dozen *G. queenslandiae* were sighted out in the open, or protruding from cover, in the early afternoon. In one instance three adults were observed climbing over the same decaying log (2 m long). Four individuals were observed with the head and/or anterior body protruding from cut logs: a further three were seen protruding from natural hollows situated low on tree trunks. All seven were observed completely motionless (until disturbed).

b. 18 April 1998. <600 m alt. Fine and sunny, 26°C. Six individuals were seen with the head and anterior body protruding from

the end of cut logs. None of the lizards were in direct sun.

c. 8 August 1998. 100-400 m alt. Overcast, approx. 27°C. Three adult skinks were observed with their heads protruding from the ends of cut logs. Another adult was observed with its head protruding from a crevice in a granite boulder.

d. 16 Jan 2000. 800 m alt. Fine and sunny, 26°C. Two adult specimens were seen with their heads protruding from cut logs beside the trail. Both lizards were in shaded situations.

e. 22 Jan 2000. 400-900 m alt. Fine and sunny, 26°C. More than six *G. queenslandiae* were observed. Some were out in the open in shaded situations on logs; others had their heads protruding from logs.

2. Mt Bartle Frere, Broken Nose trail (Start 17°26'S 145°50'E), Wooroonoran NP (Josephine Falls section).

20 October 2001. 400-850 m alt. Mostly sunny, intermittent cloud cover, 23-24°C. Five adult skinks were observed, three from crevices formed in exfoliating granite and two from cavities in rotting logs. None were observed in direct sunlight. One skink, seen protruding from the lip of a crevice, was revisited approximately four hours later and did not appear to have moved.

3. Goldfields trail (17°20'S 145°52'E), The Boulders (east side), 7 km west of Babinda.

20 January 2000. 80-140 m alt. Fine and sunny, 28°C. Four adult *G. queenslandiae* were seen with head and anterior body protruding from crevices in rotting logs (and one from a hollow in a sawn log). All were between 0.5 and 1 m above ground. While three were in shaded situations, one was in direct sunlight in a clearing beside the trail.

4. Disused logging trail, Seymour Range (17°28'S 146°02'E), 10 km north of Innisfail.

4 October 1998. 20 m alt. Fine and sunny, 27°C. A subadult was observed, beside the trail, halfway out of the end of a large hollow log. It was in complete shade.

5. Trail to Crawford's Lookout (17°36'30"S 145°46'30"E), Wooroonoran NP (Palmerston



section).

23 September 1998. 350 m alt. Overcast, 24°C. An adult *G. queenslandiae* was observed with head protruding from beneath a surface rock. It suddenly darted out and attempted to bite a small skink (*Saproscincus basiliscus*) that passed close the rock, then hastily retreated. The skink was startled by the action and quickly moved to another rock, while minutes later the *G. queenslandiae* reappeared.

### Gravid Females

Conspicuously gravid females (with enlarged ova/embryos visible through the semi-transparent ventral surface) were located between November and January and neonates between January and March. On several occasions gravid females were observed basking in direct sun. On other occasions they were found beneath relatively thin debris, exposed to direct sunlight. This would appear to represent a departure in the behaviour and microhabitat choice of gravid females, compared to non-reproductives. Several observations are described below:

1. Mt Bartle Frere (eastern) summit trail, Wooroonoran NP (Josephine Falls section), 8 km west of East Palmerston.

22 Jan 2000. 900 m alt. Fine and sunny, 25°C. An adult female was seen perched on top of an erect, partially hollow, rotting stem (0.1 m in diameter and 0.5 m high). It sat motionless in a small sunlit patch for about 5 minutes with body orientated towards the sun and ribs expanded. It retreated down the hollow when disturbed. When captured, it was found to be gravid. A second gravid female was observed 20 m further along the trail. It was basking on the ground in a small sunlit patch. It retreated into rotting vegetation that had accumulated around some surface roots. Only 10 m away, a third gravid female was located beneath a small surface rock (5 cm thick) which was in direct sunlight. It is uncertain whether movements nearby caused this female to retreat beneath the rock or whether it was discovered in situ. (It is possible that several other individuals observed

on this visit were also gravid but they could not be captured to verify this).

2. Access road to Mt Spurgeon (16°26'30"S 145°12'E), 14 km north-east of Mt Carbine township.

7 December 1996. >1000 m alt. A large gravid female was located under the bark of a sawn log at the edge of a road.

3. Access road to Mt Lewis (16°35'S 145°16'30"E), 8 km east of Julatten.

25 November 2000. >800 m alt. Fine and sunny. Two large gravid females were uncovered beneath a sheet of tin in partial sun at the edge of a clearing. Both contained three eggs.

4. Entrance to Charmillan Creek rainforest walking track (17°42'S 145°31'30"E), Tully Falls Road, 10 km south-east of Ravenshoe.

15 January 2000. 920 m alt. Fine and sunny. A gravid female was observed basking from a hollow at the centre of a sawn log with the forebody exposed to direct sunlight.

### DISCUSSION

Our observations indicate that *G. queenslandiae* exhibits a greater degree of diurnality than has previously been supposed. We would suggest that this species may not be as 'ecologically buffered' as some other log-dwelling rainforest endemics (e.g., the nocturnal *Coeranoscincus frontalis*). It is unclear whether published accounts stating that the species is nocturnal are the result of direct observation, supposition, or are based on secondary sources: Ehmann (1992: 340) comments that 'it forages secretively by day, and more openly by night...'; Covacevich and McDonald (1991: 82) state that 'activity is greatest on warm nights and in the twilight hours'; Frith and Frith (1987: 43) state 'It is active at night in search of insects'. Naylor (1980) noted 'they are almost purely nocturnal and they became severely agitated when exposed to sunlight'. His observations were based on a captive colony, housed indoors. The lack of definitive observations in the literature on this matter, and our inability to locate *G. queenslandiae* active at night in the field, suggest a closer look at the nocturnal

activity in this species is warranted.

The significance of exposing the head/anterior body from refuges is presently unclear. There are several possible explanations: (i) thermoregulation (i.e. to warm or cool the head/body), (ii) advertise an individual's presence to nearby conspecifics (involved in territoriality, acquiring mates etc.) and (iii) prey capture. The first explanation seems plausible. However, it is peculiar that so few skinks were observed in direct sun, as might be expected if thermoregulation is the primary purpose of the behaviour (especially given that many of our observations were from cool, high elevation rainforest). Furthermore, no lizards were observed protruding from logs on sunny winter days (in June-July), when the behaviour might seem advantageous. Increased time spent basking is a behaviour seen in many gravid skinks (and squamates generally) and this behaviour has been demonstrated to speed-up embryonic development (e.g., Shine, 1980). It is not surprising, therefore, that all captured *G. queenslandiae* observed in direct sun were gravid females. Explanations (ii) and (iii) may have some credence in view of observation 5. The observation could be interpreted as attempted predation (although the species is believed to be insectivorous; Greer, 1989; Ehmann, 1992) or intimidatory behaviour related to territoriality.

Finally, the cutting-up of fallen logs on walking trails may be beneficial to *G. queenslandiae* since the practice results in the creation of moist hollows that are used by the species.

#### ACKNOWLEDGMENTS

We thank the referees for their constructive comments and improvements to the manuscript.

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**Figure 1. A basking gravid female *G. queenslandiae*, Mt Bartle Frere (eastern) summit trail FNQ (see observation 1).**

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**Figure 2. An adult *G. queenslandiae* protruding from the base of a rotting stump during daylight hours, Mt Bartle Frere (eastern) summit trail FNQ**

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# NIGHT FEEDING ON A ROAD BY A FROG (*HELIOPORUS AUSTRALIACUS*)

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This note reports on a frog deliberately seeking out insect food on a roadway at night.

On 21 February 2002, I was spotlighting by car in the Cottage Point Road / West Head Road area of Kuringai Chase National Park to Sydney's immediate north. Wildlife was observed only and not retained. The following data were recorded: weather that day had been fine, hot and seasonally above average. Spotlighting was from 8.00-11.30 PM. At this time there was little wind, save for a very slight north-easterly that blew at times during the night. The sky was clear with some low see-through cloud coming over from the north-east. There was a moon in the sky all night. Air temperatures at time of drive ranged from 22-24°C.

The frog was first seen on the road on General San Martin Drive. It was about 100 m from the first toll booth near McCarr's Creek Road (the booth at the top of the hill at Terry Hills, Lat. 33° 40'S Long. 151° 13' E).

After three more passes on the same section of road I noticed that the frog was still on the road and had moved from one side of the bitumen to the other (as if crossing), but then back again to the side of the road on which it had been originally seen. Whether by chance or otherwise, the frog always seemed to be in the area of the road which allowed cars to pass over it (on one or other side of the centre of the road), with the wheels on either side of the frog. As a result of this observation, I pulled up near the frog on the fourth pass. I then turned off the car's engine and headlights and observed the behaviour of the frog, which apparently ignored my presence. All this was possible due to the good illumination provided by the moonlight; the fact that I

remained still at materially relevant times and the added help provided by the headlights of passing cars. Over the next twenty minutes ten cars were observed to pass the frog, either over it, or on the other side of the bitumen. Following the passing of a car directly over the frog it would move its body around in a circular motion, as if looking for fallen insects. Generally the frog wouldn't move away, unless it took up an insect; when it would hop towards the food and lap it up. This was observed twice.

In general the traffic was leaving the park and hence the frog was situated on the same side of the road along which this traffic was moving. However, on one occasion a car passed on the opposite side of the road to the frog. The frog responded by hopping across the roadway to where this car had passed and positioned himself on that side of the road in the path of more oncoming traffic. Within a few minutes another car passed on the other side of the road (leaving the National Park) with the frog moving back to that side of the roadway.

After observing the frog's behaviour for 20 minutes, I continued spotlighting for about another 40 minutes, noticing that the frog continued to hunt and feed in the path of oncoming traffic (when I passed this spot). On the final pass of this piece of road at about 11.30 PM, the frog was still alive and well and sitting in the path of oncoming cars.

In all, well over 20 cars must have passed over the frog, but it was never hit.

## DISCUSSION

Over the period 1978-2002 I have regularly driven the roads of the West Head/Cottage

Point area of Kuringai Chase National Park at night in search of herpetofauna. With more than 100 night drives over this time in all kinds of weather conditions deemed likely to yield reptiles and frogs, I feel that I have a good grasp of the habits of most reptiles and frogs in the area in terms of their likely nocturnal movements and associated habits (Hoser, 1984a, 1984b, 1989).

The preceding instance of road feeding by an adult *Helioporus australiacus* at night is the first such case I have observed. That the behaviour is not common, would be assumed on the basis that specimens that do this would soon be hit and killed by passing traffic. However, as few people who go spotlighting for frogs on roads at night actually stop to observe the behaviour of the frogs seen, the behaviour observed may be more common than previously thought. There is also a possibility that some frogs may seek out roads for the purpose of finding food.

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# CAPTIVE FROG EGG NUMBERS – A MISLEADING INDICATOR OF BREEDING POTENTIAL

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Clutch size in animals has been the subject of considerable attention. The number of embryos produced per female per breeding episode may influence the number of individuals reaching maturity (Gould, 1966). This number may also evolve as one of a combination of inter-related life history traits and may thus show both intra and inter-specific variation (e.g., Elmberg, 1991; Tyler, 1994; Halliday & Tejudo, 1995). This variation may reflect other aspects of the biology of the animals involved (Lomar & Madsen, 1986).

Clutch size in frogs has been recorded under a variety of circumstances. Counts of eggs have, for example, been made after frogs have been observed to spawn in the wild (e.g., Long, 1987), after amplexing pairs have been removed from the wild and subsequently observed to spawn in captivity (e.g., Martins, 1993), and after mating and spawning have occurred amongst captive-maintained individuals (e.g., Hillis *et al.*, 1984). In some cases spawning has been stimulated by chemical injection (e.g., Brown & Tyler, 2002).

Such variation in circumstances could influence frog clutch size and hence confound attempts to make inter-specific comparisons. Captive frogs could, for example, be better nourished than their wild counterparts and hence produce greater numbers of eggs. On the other hand, captive frogs may not experience conditions that stimulate mating and spawning and hence could show relatively reduced clutch sizes. Similarly chemical stimulation could lead to premature egg laying and hence reduced clutches or could enhance spawning and hence result in relatively large clutches. Apparently, however, there are presently no studies that examine possible effects of these and other factors on clutch

size in frogs. There are similarly no studies that consider the effects of these differences in circumstances on the duration of amplexus, the fertility of the eggs or the behaviour of the frogs.

In this paper we shall compare captive and wild Green and Golden Bell Frogs *Litoria aurea* in terms of observed clutch sizes, times spent in amplexus, egg fertility and associated behaviour. Our results reinforce that captive *L. aurea* have the largest recorded clutch size of any Australian frog species (Pyke & White, 2001) (not *L. splendida* as reported by Brown & Tyler, 2002) and show how inappropriate it is to infer information about breeding potential in wild frogs using captive reproductive data.

## MATERIALS AND METHODS

### Clutch Size

In frogs, clutch size can be quite variable and depend on the number of episodes of amplexus. To highlight the differences between egg numbers produced during each amplexus, we define clutch size to be the number of eggs laid per spawning event where a gap of 10 minutes or more between periods of egg laying has occurred. We adopt this definition because it appears that females in the wild do not resume egg laying after such breaks (see below). We similarly consider distinct periods of amplexus to be those separated by breaks of 10 minutes or more.

### Captive Frog Populations

We have observed spawning by captive *L. aurea* derived from three populations, all from sites within metropolitan Sydney. Two of these populations, Rosebery and Arncliffe,



have been maintained at Sydney's Taronga Zoo since 1994 and 1999 respectively. The third consisted of frogs captured at Kurnell between 1998 and 2000 and maintained at the home of the senior author until after spawning. Further details concerning the locations and descriptions of these sites may be found in White and Fanning (1994), Pyke and White (1996) and White and Pyke (1996).

At Taronga Zoo, frogs were kept in outdoor enclosures for most of the year but, when a female frog was observed by abdominal inspection to be gravid, it and a mature male (i.e., one that had been calling) were transferred to a glass aquarium measuring approximately 50 cm x 30 cm x 30 cm in which there was an area of open water as well as an area of land above water level. The aquaria were housed in rooms with no exposure to natural light but an artificial light cycle of 8 hours darkness and 16 hours light (Reptilight tubes) and a constant temperature of 23°C. Spawning generally occurred within two to five days of pairing. Most observations were made by zoo staff.

Four pairs of frogs from Kurnell were kept in plastic aquaria measuring approximately 30 cm x 25 cm x 30 cm. The aquaria were housed in an unheated garage and received sunlight via a window. Air temperatures ranged from 16° to 25°C during the holding period. In two cases amplexus occurred within about 10 minutes of when the frogs were put together. All animals were fed calcium-dusted crickets and mealworms.

At Taronga Zoo, frogs that had not amplexed when placed together in an aquarium were checked several times per day between 8am and 4pm. After amplexus was observed to have begun, a mating pair was (when possible) observed at about 30 minute intervals until amplexus had ceased or until 5pm. In the latter case the pair was checked again the following day commencing at about 7.30am. Each observation lasted 1-5 minutes and notes were taken of whether the pair was in amplexus and whether eggs were laid.

Though at least 30 spawning events by *L. aurea* were recorded at Taronga Zoo between 1994 and 1999, it was possible to make such detailed observations for just 11 mating pairs.

The Kurnell frogs were observed continuously until amplexus had commenced and then at intervals of about 5-10 minutes until amplexus had ceased for at least 10 minutes or until the frogs separated. In the latter case observation recommenced at about 6am the next day. Checking continued whenever frogs were found to have recommenced amplexus. Each observation lasted 1-2 minutes and observations were recorded as above.

For each mating pair the recorded time in amplexus was taken to be time between when amplexus was first observed and the time when it was last observed. If amplexus ceased and the frogs separated and later recoupled, the duration of each break in amplexus was taken to be the time between when amplexus first ceased and the last observation time before amplexus recommenced. The number of periods of amplexus was taken to be one plus the number of observed breaks in amplexus. The first period of amplexus is described by us as the primary amplexus period and later ones secondary periods.

Eggs from all three populations were counted in the same manner. Following amplexus, spawning and a period in which amplexus did not recommence (30 minutes at Taronga Zoo; 10 minutes for Kurnell frogs), eggs were placed in a shallow flat container with enough water to cover them and counted in small clusters that could be easily teased apart from other eggs and moved from one part of the container to another. With this technique eggs should have been counted with negligible error. It was possible to obtain egg counts for ten spawn masses at Taronga Zoo and two for the Kurnell frogs.

Other opportunistic behavioural observations were made and recorded at Taronga Zoo including observations of female frogs attempting to dislodge amplexed males.

Hatching rates were determined for ten spawn masses from ten separate pair matings in the following manner. The spawn masses chosen were dictated by our ability to get to the Zoo that day. Each spawn mass was removed from the container in which amplexus and spawning had taken place, counted and then placed in a separate water-filled aquarium measuring 50 cm x 30 cm x 30 cm. After 5 - 10 days, when no further hatching took place, the number of tadpoles (dead or alive) was counted and the percent hatching was calculated. Dead tadpoles were removed from the aquaria on a daily basis.

### Wild Frogs

During field work between 1990 and 2002 observation of amplexus and spawning by *L. aurea* and egg counts were made at the following seven sites: Rosebery, Kurnell, East-lakes, Enfield, Arncliffe, Coomonderry and Broughton Island (for descriptions of these sites see White and Fanning, 1994; Pyke and White, 1996, 2001 and White and Pyke, 1996). Frogs which later paired were most often encountered at night, all were in free-standing water, and in each case the mating pair was observed prior to spawning to reduce the possibility of the observer confusing primary and secondary spawning events.

Amplecting pairs were continuously observed with the aid of a low-beam headlamp at a distance of about 2-4 m from the frogs. Time of initial encounter was recorded along with times of any of the following events: commencement of egg laying, cessation of egg laying, cessation of amplexus, number of male frogs attempting to amplex, and the behaviour of the female frog to males frogs after spawning. After amplexus had ceased the distance between the two frogs was recorded along with any changes in location by either frog and the nature of encounters with other frogs until one or other of the frogs was no longer visible.

It had previously been observed that, after amplexus, the females remained within 25 cm of the male for a minute or two and then

moved quickly to distances of 2 m or more from the male and then out of sight, while during the same time the males moved little. The time spent by the female within 25 cm of the male following amplexus was therefore recorded. It has been possible to observe 14 mating pairs in this manner.

When possible the number of eggs per spawn mass was counted. Spawn masses were collected from the water surface (before they had sunk) and were placed in a clean sorting tray (along with any grass or vegetation that was entangled with the spawn). The spawn was then sub-divided into smaller, manageable clumps of between 20 and 50 eggs for counting. In most cases the spawn mass was restored and returned to where it had been collected. In two cases the entire spawn was retained to record hatching success in the same manner as for the captive populations.

In addition, at Kurnell, five trials were carried out using females that had spawned and were considered to have departed the immediate breeding area once they were observed to move away from the male and the water after amplexus and were at least 2 m from both when captured. Each female frog was returned once to the breeding site within ten minutes of leaving the area and then observed continuously as described above for 30 minutes or until it disappeared. Any interactions between these females and other frogs in the breeding site were recorded.

### Statistical analyses

For most parameters (i.e., clutch size, time in amplexus) the observed frequency distributions for both wild and captive frogs showed no significant departures from normal distributions (Kolmogorov-Smirnov test,  $p$ 's > 0.25). The mean values of these parameters for wild and captive frogs were therefore compared with a two-tailed Student *t*-test. To reduce departure from a normal distribution, hatching proportions were arcsine transformed. The relationship between this transformed variable and clutch size was then evaluated using linear regression. For com-

parison, this analysis was repeated for the untransformed proportion.

## RESULTS

### Duration of Amplexus

Egg laying was only observed during amplexus. If amplexing frogs separated and then later recoupled egg laying was not observed during the period of separation.

Amplexus in captivity often involved more than one period of coupling and more than one period of spawning, whereas no breaks in either amplexus or spawning were ever observed in the wild. In captivity, there was no recorded break in amplexus for one of 15 pairs observed, single breaks in amplexus were recorded for seven pairs and two or more breaks for another seven pairs. Seven of these 15 frogs had additional breaks in spawning within a single period of amplexus, while eight did not. In total there were 23 breaks in spawning recorded for these 15 frog pairs, resulting in five observed instances of secondary egg release and two of tertiary spawning.

Frogs in captivity showed significantly greater recorded total time in amplexus than did wild frogs (Table 1; Student *t*-test,  $p = 0.02$ ).

### Egg Numbers per Spawn Mass

Frogs in captivity produced spawn masses which on average contained significantly more eggs than frogs in the wild (Table 1; Student-*t* test,  $p = 0.004$ ). The observed maximum and minimum numbers of eggs per spawn were also higher for captive vs wild frogs (i.e., maxima: 11920 vs 6380; minima: 2945 vs 1960).

For spawn from captive frogs there was a steep and significant decline in the proportion of eggs that hatched with increasing numbers laid (Fig. 1; linear regression: proportion vs egg number,  $p = 0.000$ ; arcsine(proportion) vs egg number,  $p = 0.000$ ). The small sample size of hatching percentages for wild

frogs meant that it was not possible to determine whether there was any additional difference between captive and wild spawn (Fig. 1). Largely or entirely because of the negative relationship between hatching percentage and clutch size, the average hatching percentage for captive spawn was markedly lower for captive spawn than for wild spawn (Table 1; Fig. 1).

### Behaviour of Field and Captive Female Bell Frogs immediately Post-spawning

After amplexus in the wild female frogs generally left the vicinity of the male and departed from the breeding area within about 20 minutes. The time that females spent within 10 m of the spawning site ranged from 2 to 21 minutes and averaged just 7.2 minutes ( $n = 14$ , s.e. = 1.4). Within captivity, on the other hand, amplexing pairs were forced to remain in close proximity continuously.

In wild populations, female frogs were observed to move quickly away from the male after spawning had been completed and the pair disunited. In 17 out of 18 observations of spawning the female moved more than 50 cm away from the male in less than 30 seconds of the termination of amplexus and in 16 of these cases, the female frogs initially moved between 50 cm and 150 cm away from the male.

If the female was approached by the same male or other males she would attempt to repel these advances, and would quickly depart the breeding pond and move into vegetation away from the pond. On seven occasions, females were observed to be grabbed by males as they attempted to depart the breeding pond and in all but one case the female frogs responded by kicking the male frogs away using their back feet before disappearing into the nearby vegetation. On one occasion, a small male frog was observed to successfully grasp a female as she departed the pond and this female continued to hop away from the pond carrying the attached male. This female, with the male still attached, was followed using a low-beam



head lamp for about 20 m until she could not be relocated.

Translocation of female frogs back to where they had spawned resulted in the same behaviour. In four out of five instances they were pursued and grabbed by male frogs. The females struggled violently to escape the male frogs and all departed the site within a minute of being released there.

Behaviour in captivity was similar with males generally attempting to re-amplex with females within 1 to 5 minutes after spawning and females attempting to resist these advances. In 15 of 16 cases the male attempted to re-amplex with the female and the female tried to dislodge the male by kicking him away with her hind legs. However, unlike the wild situation, males were ultimately successful in re-amplexing with the females in captivity. In 12 of the 15 cases the female dislodged the male one or more times but in all these cases the male repeated his advances and was eventually successful. In all cases the females eventually ceased trying to dislodge the male. These secondary bouts of amplexus lasted 2 to 57 hours.

During secondary amplexus, females were observed to release eggs in seven out of sixteen cases. When egg release occurred the secondary clutch size was always smaller than primary clutches, egg size was also smaller and many of the eggs appeared infertile. In two instances, eggs from secondary egg masses were collected and examined and found to contain relatively small eggs, many of which did not contain visible yolk and were presumably infertile (P. Osborne pers. comm.).

## DISCUSSION

### Duration of Amplexus

Given the methods that were adopted, the times spent in amplexus are likely to have been underestimated but this does not affect the comparison between captive and wild

behaviour. Since amplexus by zoo-captive frogs could have commenced anytime between about 5pm when the last daytime check of frogs was made and around 7.30am when amplexing frogs were first encountered, the average time spent by the frogs in an amplexus for frogs in captivity was probably about six hours greater than actually recorded and hence was probably about 34 hours duration on average. Amplexing frogs in the wild were under continual observation and this may have affected the duration of amplexus. Taking these biases into account, the actual differences between captive and wild frogs in terms of time spent in amplexus are still great.

Since breaks in amplexus and/or spawning for captive frogs that occurred during the night would have been missed, the actual difference between captive and wild frogs in terms of the frequencies of these breaks would also have been greater what was recorded.

Amplexus and spawning by *L. aurea* in captivity and in the wild are therefore very different affairs. In the wild amplexus and spawning are uninterrupted and last only a few hours and, after amplexus is over, females generally depart from the breeding area within a few minutes while resisting any advances from further suitors. In captivity, where male and female are confined together, both amplexus and spawning are much protracted and have many breaks.

### The Significance of Clutch Sizes

Spawning by captive and wild *L. aurea* are apparently similar in terms of the number of resulting tadpoles but differ in terms of clutch size and hatching success. The average clutch size in the wild for this species is about 62.3% of that in captivity (i.e., 3760 vs 6047 eggs/spawn) and almost all (i.e., 96%) of the wild-produced eggs hatch. Assuming that this hatching percentage is generally applicable to all wild spawn, the estimated initial number of tadpoles per wild clutch is 3610. In captivity, however, the proportion (P) of eggs that

hatch into tadpoles was found to decrease with increasing number ( $n$ ) of eggs laid according to the estimated equation  $P = 1.02 - 5n/100,000$ . From this relationship the estimated numbers of tadpoles per clutch is 4340 for captive frogs. These estimated numbers of tadpoles per clutch for captive and wild spawn are not significantly different if the hatching percentages are assumed to be determined without error (Student  $t$ -test,  $p = 0.20$ ) and hence would not be significantly different if allowance were made for error in the hatching rates.

It may therefore be misleading to use estimates of clutch size obtained for captive frogs, especially in comparing different species, and counts of initial numbers of tadpoles may provide a better basis for comparison. Captive situations, where females are unable to escape the sexual advances of males, may lead to observations of unnaturally high clutch sizes. It is therefore difficult to compare different Australian frog species as most accounts of egg numbers do not indicate whether the frogs were maintained in captivity or located in the wild and few provide information regarding hatching success (e.g., Tyler, 1994).

It is nevertheless clear that *L. aurea* has the largest recorded captive clutch size for any Australian frog. We recorded a clutch of 11920 eggs in the present study, van de Mortel (1996) recorded one of 11682 for the same species. The next largest recorded clutch size was 10363, recorded for a captive-maintained pair of *L. splendida* by Brown and Tyler (2002). However, these frogs were stimulated to spawn through chemical injection (Brown & Tyler, 2002) and so may have produced an unusually enhanced clutch size.

### Evolution of clutch size

There is apparently a trade off between clutch size on the one hand and egg viability as measured by egg size, whether or not an egg contains yolk, and hatching success on the other. Hatching success decreased with

increasing clutch size in the present study (Fig. 1). Eggs in secondary clutches were noticeably smaller than eggs in primary clutches and so average egg size would have decreased with increasing clutch size. The proportion of eggs without yolk was also observed to increase markedly from primary to secondary clutches. Eggs that are relatively small and contain little or no yolk are likely to produce a low proportion of small tadpoles (e.g., Tejedo, 1992).

Since female body reserves are limited, it follows that there may be strong selection against the natural production of very large clutches. Females that produce relatively large clutches with low hatching rate and hatchling size may make little more contribution to the next generation than females that produce smaller (but more fertile) clutches. Production of large clutches may also diminish body reserves to the point that females are unable to reproduce the following year (Bull & Shine, 1979).

### The Behaviour of Female Frogs Post-spawning

The observations that female frogs remove themselves from breeding sites quickly after spawning suggests that there are disadvantages in remaining at the breeding site after spawning. These disadvantages could be that female frogs may be re-amplexed, forced to expend energy attempting to repel unwanted suitors and sometimes forced to secondarily spawn. Male Bell Frogs do not appear to be able to distinguish between a female that has spawned and one that is gravid. A mature female Bell Frog in close proximity to a reproductive (not necessarily calling) male may be amplexed (and forced to release small eggs). That females in captivity eventually cease attempting to remove re-amplexing males suggests that they may become tired from this activity. Consistent with this was the observation that a re-amplexed female at Taronga appeared unable to keep her head above water and was considered in danger of drowning (D. Hobcroft, pers. comm.). Breeding sites may also be relatively inferior in

terms of foraging or shelter. For these and other reasons, female frogs may choose to avoid breeding ponds at all times except when their body reserves are sufficiently high to spawn and produce normal sized eggs. This could explain the high ratios of adult male numbers to adult female numbers that are typically observed at *L. aurea* breeding sites (White & Pyke unpubl.).

### ACKNOWLEDGMENTS

The staff of Taronga Zoo's Serpentaria were particularly helpful in providing observations and care for captive frogs. Special thanks goes to Dion Hobcroft, Paul Osborne, Candice Webb and Trent Russell.

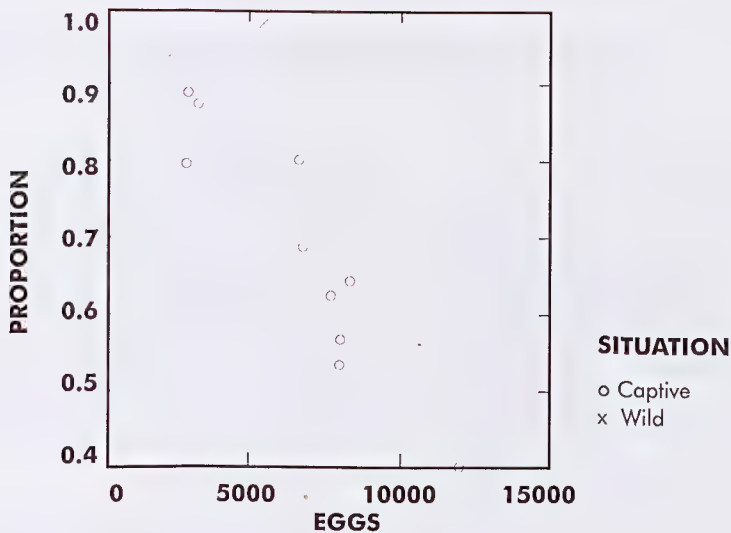
Licences issued by the NSW National Parks and Wildlife Service enabled this project to proceed: licence no. A 1331 (AW) and A2410 (GP). In addition, the NSW Dept of Agriculture Animal Care and Ethics Committee approval for the project was DG ACEC 65/96.

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**Figure 1. Proportion of eggs hatched vs clutch size**



**Table 1. Comparison of Captive and Wild Green and Golden Bell Frog Reproductive Data (mean  $\pm$  s.e.; n=sample size)**

	Captive Frogs	Wild Frogs
Time in Amplexus (hours)	28.4 $\pm$ 7.6 (n=15) Range: 1.25-116.5	2.3 $\pm$ 0.9 (n=8) Range: 0.5-7.5
No. of Eggs/Spawn	6047 $\pm$ 804 Range: 2,945-11,920	3760 $\pm$ 284 Range: 1,985-6,380
Proportion Hatching	0.68 $\pm$ 0.05 (n=10) Range: 0.40 –0.89	0.96 $\pm$ 0.02 (n=2) Range: 0.94-0.98
Time Female Remains after Spawning (minutes )		7.2 $\pm$ + 1.4 (n=14) Range: 2-2

# SURVEYS FOR THE STUTTERING FROG *MIXOPHYES BALBUS* ON THE SOUTH COAST OF NEW SOUTH WALES

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## ABSTRACT

Systematic targeted surveys for the Stuttering Frog *Mixophyes balbus* were conducted on the south coast of New South Wales during November 1999 to April 2000. One hundred and thirty sites were surveyed during the day and 84 at night. *Mixophyes balbus* was detected at four sites, two of which were historic. The detection rate for *M. balbus* was 0.8% of diurnal and 4.8% of nocturnal sites surveyed. The species was not detected at 12 historic sites. A comparison of previous records of *M. balbus* with the sites where the species was detected indicated a decline in distribution and abundance since the 1970's. No *M. balbus* were found during the current survey above 300 m asl. Chytrid-affected Lesueur's Frogs *Litoria lesueuri* were found at one extant *M. balbus* site.

## INTRODUCTION

The Stuttering Frog *Mixophyes balbus* has declined in southern NSW and few animals have been detected over the last decade (Daly, 1998; Lemckert *et al.*, 1997). The species is currently listed on Schedule 1 of the Threatened Species Conservation (TSC) Act 1995 as Endangered.

The habitat specificity, documented decline and paucity of information on the *Mixophyes* species prompted the NSW National Parks and Wildlife Service (NPWS) to initiate surveys of *M. balbus* on the south coast of New South Wales.

Surveys of frogs in southern NSW have been mostly opportunistic and confined to certain geographic areas (Lunney & Barker, 1986;

Webb, 1991; Murphy & Daly, 1996; Goldingay *et al.*, 1996; Daly, 2000). The exception was surveys conducted as part of the southern Comprehensive Regional Assessment (CRA) from 1997-9. Although the CRA surveys did not target *M. balbus*, tadpoles of the species were found at Big Belimba Creek, north-west of Narooma (GD and MP pers. obs.). Adult *M. balbus* had been previously detected at this site during pre-logging surveys conducted by State Forests of NSW (Lemckert *et al.*, 1997).

The aim of our survey was to assess historic and potential sites to determine the species' status and habitat preferences on the south coast of NSW.

## METHODS

### Survey area

The survey area (Figures 1 and 2) extended from the Illawarra Highway (Macquarie Pass National Park, 34°33'S 150°39'E) in the north to the New South Wales/Victorian border (37°18'S 150°45'E). Surveys were conducted at sites where *M. balbus* had previously occurred (historic sites) and in other suitable habitat for the species (potential sites).

### Site Selection

Prior to the commencement of field work, previous records of *M. balbus* were reviewed. The records reviewed included those from the Australian Museum, State Forests of NSW, NPWS Wildlife Atlas, Australian Wildlife Collection (CSIRO, Canberra), NPWS CRA Southern Region records and unpublished data. State Forests' regional ecologists were

contacted and Messrs A. Douche (Narooma), C. Slade (Eden) and B. Smith (Narooma) gave valuable information of *M. balbus* in their management areas. Some of this information was not on existing databases. Where possible, sites were marked on 1: 25000 topographic maps and formed the basis for selecting historical sites to survey.

Other survey sites were selected by a variety of methods. In the Eden Management Area (from the NSW/Vic. border to north of Bega ie Mumbulla State Forest), one author (DC) had conducted surveys for large forest owls from 1994-8. Many of these sites were in gullies and had floristic and fluvial attributes which were considered indicative of potential habitat for *M. balbus*. Those located in the upper portions of creeks that had riffle zones were selected for survey. The vegetation was mostly tall open forest that had a closed forest midcanopy.

Other sites in potential habitat were selected on the basis of proximity to historical sites or were in the upper reaches of creeks on the escarpment and ranges. These sites were selected by viewing topographic maps and locating creeks that were accessible by road. These were surveyed during the day and a subset that was considered to have the most suitable habitat was re-surveyed at night.

The habitat features that were considered to be suitable for *M. balbus* were: relatively flat creeks less than 5 m in width that had riffle zones, and tall open forest with an abundance of ferns (King Fern *Todea barbara*, Rough Tree Fern *Cyathea australis* and Soft Tree Fern *Dicksonia australis*) on their edges.

### Diurnal Searches

Diurnal searches were conducted between 22 November 1999 and 28 April 2000 and involved walking along creeks and looking for frogs, tadpoles and spawn. Generally two surveyors worked together, one surveyor would walk upstream and the other down stream of the access point. In this way approximately 500 m. of each creek was searched. Areas of open water such as pools

and potholes were dip netted, tadpoles identified and released.

Frog species present were identified by call or direct observation of adult frogs, tadpoles or spawn masses.

### Nocturnal Searches

Nocturnal searches involved spotlighting approximately 250 m of each creek edge for 30 minutes. Each surveyor used fifty watt/12 volt spotlights. Calls of *M. balbus* were broadcast continually from a cassette player (Optimus CTR-116) while the survey was in progress. The volume of the broadcast call was similar to that given by *M. balbus* in the field. Surveys were conducted from 12 October 1999 - 17 February 2000 between 1930hrs and 2215hrs Eastern Standard Time (EST) when air temperatures were 15°C or greater.

Like the diurnal searches, one person would survey upstream and the other down stream of a common access point. The search area for spotlight surveys was confined to the edge of the creeks. Small pools and side arms of creeks were targeted for tadpoles. Fish observed during spotlight surveys were also identified.

### Resurvey of known *M. balbus* sites

Two of the sites where *M. balbus* was detected during the 1999 - 2000 surveys were resurveyed. *Mixophyes balbus* calls were broadcast from a walkman during diurnal surveys. The Macquarie Pass National Park site was resurveyed on the 26 November 2002 and the Big Belimba Creek site was resurveyed on 30 April 2002.

### Survey Hygiene

An amphibian chytrid fungus has been recently identified as a cause of death of frogs in Australia, and a potential cause of the decline or disappearance of several Australian frog species (Berger et al., 1999). In order to reduce the risk of infection and spread of this fungus, equipment such as dip nets and shoes were thoroughly cleaned with



bleach, prior to conducting surveys.

Sick and dying frogs and dead spawn were collected, frozen and sent for pathological examination. The spawn was sent to Mr M. Fox (Illawarra Medical Laboratories) and frogs to either Dr M. Mahony (University of Newcastle, NSW) or Ms D. Mendez (James Cook University, Qld).

Sick frogs were collected by inverting plastic clip bags and using them as a glove. This method avoided direct contact with the animals. The frogs and spawn were then frozen. The frogs were sandwiched between ice bricks and dispatched via express courier (next day delivery) in eskies.

### Habitat Assessment

The habitat of sites selected for nocturnal surveys was assessed. Details of location (grid reference), disturbance history (logging, fire, grazing, weeds, flooding), adjacent vegetation (height and species of canopy, mid-canopy and shrublayer), depth of leaf litter and soil and fluvial components (stream order, gradient, depth of water, colour of water, width of creek, substrate, presence of riffle zones and small pools, logjams, stream bank structures such as overhanging rocks and earth overhangs) were recorded. Fish observed during the surveys were recorded.

## RESULTS

### Survey sites and survey effort

One hundred and thirty sites were surveyed during the day (Table 1, Figure 1) and eighty four sites were surveyed at night (Table 1, Figure 2). Twenty five of these sites were searched both during the day and night. *Mixophyes balbus* was detected at only four sites. The detection rate for *M. balbus* was 0.8% of diurnal and 4.8% of nocturnal sites surveyed. In relation to the total number of frogs detected during nocturnal searches *M. balbus* was comparatively rare constituting 0.6% of detections. The survey effort involved approximately 100 hours surveying about 25 kilometres of creeks during the day and 42

hours spotlighting 21 kilometres of creeks.

### Assessment of Historic Sites and Possible Causes of Population Disappearances

*Mixophyes balbus* was historically known from 15 sites within the study area (Figure 3). Twelve of these sites were examined during the current survey (Table 3). One site was not surveyed because of difficulties with access (the upper reaches of Mongarlowe River were blocked by fallen trees), another site could not be located by either grid location or description (Currambene Creek at Minuma Range Fire trail, Shoalhaven River system) and the third site was surveyed by a third party (A. White (pers. comm.) surveyed Bundanoon and did not detect *M. balbus*). The grid references of some historic records, when located on the ground were considered unsuitable habitat. It would therefore appear that there were inaccuracies in some of the location data. Four of the sites (Stoney Creek, Germans Creek, Hopping Joe Creek, and Flat Rock Creek) were not surveyed at night because they were dry or reduced to isolated pools.

Pathogens, habitat destruction and exotic species of fish were noted at historic and current sites.

### Extant *Mixophyes balbus* sites

*Mixophyes balbus* was detected when males responded to call playback during nocturnal searches at Big Belimba Creek, north-west of Narooma (two animals) and Red Creek, west of Cobargo (one animal) on 14 and 16 January 2000 respectively. The species had previously been detected at Big Belimba Creek (Lemckert *et al.*, 1997; GD pers. obs.) Tadpoles were found at Macquarie Pass National Park, which was a historic site. Approximately 30 tadpoles were found in a 6 x 10 x 1.5 m deep pool (tributary of Macquarie Rivulet) at Macquarie Pass National Park. The species was not detected at 12 historic sites (Table 2).

## Description of extant sites

### Macquarie Pass National Park

The site (elevation 300 m AHD) was adjacent to cleared farmland and showed signs of logging, grazing, flooding and weeds. The soil was shallow (> 50 mm) and consisted of sedimentary deposits of sandy loam. The emergent trees were Two-veined Hickory *Acacia binervata* and Maiden's Wattle *A. maidenii*. The midcanopy contained Lillypilly *Acmena smithi* and the shrublayer Rough Tree Fern *Cyathea australis* and King Fern *Todea barbara*. Exotic weeds (Crofton Weed *Ageratina adenophora* and Wandering Jew *Tradescantia albiflora*) were present. Leaf litter and humus depth was shallow (0 - 20 mm).

The pool where the tadpoles were found was situated below a bridge. The culvert under the bridge was rectangular and constructed of concrete. The water flowed over a concrete floor at a fairly even depth (approximately 30 mm) and velocity. The substrate under the distal edge of the culvert floor had been eroded and a narrow, moist undercut had formed immediately above the pool.

The tadpoles were fairly uniform in size being about 50 mm in total length. Based on previous experience (Daly, 1998) they were estimated to be several months old. They were concentrated in shallow water and swam between the spaces of rocks when disturbed. The pool also contained native species of fish (galaxia and gudgeons) and eels were observed in other sections of the creek.

### Big Belimba Creek

The site (elevation 230 m AHD) showed no signs of logging, fire, grazing or weeds. The soil was deep (< 50 mm) and consisted of sedimentary deposits of sandy loam. The emergent trees were River Peppermint *Eucalyptus elata*. The midcanopy was Grey Myrtle *Backhousia myrtifolia* and the shrublayer contained tree ferns *Cyathea australis* and *Dicksonia antarctica*. On the edge of the creek there were other species of fern including

*Todea barbara*, Batswing Fern *Histiopteris incisica* and False Bracken *Calochlaena dubia*. Leaf litter and humus depth was shallow (0 - 20 mm).

The third order creek had clear, moving water. The substrate consisted of gravel and rocks. Log jams, riffle zones and side pools were common. The stream banks had rock and earth overhangs. The creek width varied from 5-10 m and water depth from 1 - 0.015 m. The height of debris beside the creek indicated signs of severe flood. Fish observed in the creek included smelt, gudgeons, eel and yabbies.

Two males were detected when they responded to call playback. The animals were approximately 100 m apart and were positioned under the dead fronds of ferns and leaf litter within one metre of the creek.

### Red Creek

The site (elevation 60 m AHD) showed no signs of logging, grazing or weeds. There had been light fire and moderate flooding. The soil was shallow (> 50 mm) and consisted of sedimentary deposits of sandy loam. The emergent trees were Manna Gum *Eucalyptus viminalis* and River Oak *Casuarina cunninghamiana*. The midcanopy contained Grey Myrtle *Backhousia myrtifolia* and various wattles *Acacia mearnsii* and *A. floribunda*. The shrublayer contained Bracken *Pteridium esculentum*. Leaf litter was shallow (0 - 20 mm) and humus absent.

The second order creek had clear, flowing water. The substrate was gravel and rocks. Log jams, riffle zones and side pools were common. The creek width varied from 5-10 metres and water depth from 1 - 0.015 metres. The height of debris beside the creek indicated signs of flood. Eel and yabbies were observed in the creek.

One *M. balbus* was detected when it responded to call playback. The animal was approximately 30 m from the creek and positioned in dense vegetation.

## Other frog species

Thirteen species of frog were detected during the diurnal searches, mostly by the identification of tadpoles (Table 1). Ten species were detected during nocturnal searches. On a presence basis the most commonly encountered species were the Southern Leaf Green Tree Frog *Litoria nudidigitus* (43% of diurnal and 75% of nocturnal sites), Lesueur's Tree Frog *L. lesueuri* (35% of diurnal and 51% of nocturnal sites), the Common Eastern Froglet *Crinia signifera* (19% of diurnal and 43% of nocturnal sites) and the Blue Mountains Tree Frog *L. citropa* (17% of diurnal and 27% of nocturnal sites). The total number of frogs detected (heard and or observed) during nocturnal searches was 462 (Table 2). The most common were *Litoria nudidigitus* (43% of detections), *Crinia signifera* (22% of detections), *L. lesueuri* (19% of detections) and *L. citropa* (11% of detection).

In addition Littlejohn's Tree Frog *L. littlejohni*, Bleating Tree Frog *L. dentata*, Eastern Pobblebonk *Limnodynastes dumerilii*, Haswell's Frog *Paracrinia haswelli* and Dwarf Tree Frog *L. fallax* were detected opportunistically.

Four extensions of range were made: *L. littlejohni* tadpoles in Bruces State Forest south of Eden (approximately 50 km eastern range extension), *L. dentata* south of Eden (Two Fold Bay Caravan Park, approximately 50 km southern extension), *L. fallax* at Ulladulla (presumably a translocated population, approximately 150 km south of known occurrence) and *Limnodynastes tasmaniensis* west of Moruya (probably translocated approximately 50 km east of known occurrence).

The response call given by *L. citropa* to the broadcast of *M. balbus* was atypical as the first portion of the call was deleted and the latter part modified so that the sound resembled that given by *M. balbus*. The difference in response was that *M. balbus* called three or four times after the cessation of the broadcast and then called again three to four times after subsequent broadcasts. Conversely, *L. citropa* only called once or twice after initially hearing

the broadcast and then remained silent.

## Fish

Fish and Yabbies *Euastacus* spp. were present in most of the creeks. The fish included Eel *Anguilla* spp., Climbing Galaxia *Galaxia brevipennis*, Spotted Galaxia *G. maculata*, Gudgeons *Gobiomorphus* spp., and Smelt *Retropinna semoni*, Grayling *Prototroctes maraena* (White Rock Creek) and Trout *Salmo trutta*. The Mountain Galaxia *G. olidus* was found in the Mongarlowe River. The Brown Trout *Salmo trutta* was found in three creeks above 680 m (Mongarlowe River, McCarthy's Creek and Bemboka River). Frogs and tadpoles were uncommon or absent from these creeks.

## Sick or dead frogs

Two moribund *L. lesueuri* were found at Big Belimba Creek. One was sent to Dr M. Mahony (Newcastle University) and the other to Ms D. Mendez (James Cook University). Amphibian chytrid fungus was identified in both specimens.

Dead spawn of *L. nudidigitus* was found at several sites. The dead eggs were white and the number of dead eggs per spawn mass varied. At Ludwig's Creek all 21 spawn masses observed were dead. Cultures of one affected batch of eggs by Illawarra Medical Laboratories identified the fungi *Penicillium* sp. and *Acremonium* sp as present. The laboratory report stated that the *Penicillium* was possibly due to airborne or environmental contamination.

## Habitat Assessment

On the south coast of NSW, *M. balbus* occurred in a wide range of vegetation communities that included cool temperate closed forest (*Eucryphia moorei*); subtropical closed forest (*Toona ciliata*, *Dendrocnide excelsa*) and tall open forest (*Eucalyptus cypellocarpa*, *E. fastigata*, *Syncarpia glomulifera*, *E. botryoides/saligna* cross) (Table 3). Webb's (1991) and Murray Littlejohn's (unpublished records) sites of *M. balbus* on the NSW/Vic border were in open forest (*E. cypellocarpa*). The



understorey vegetation at Flat Rock and Hopping Joe was not as mesic as other sites.

The altitudinal range of the species at historic sites in the study region was 40 - 790 m asl. The average altitude of these sites was 353 m ( $n = 15$ ,  $SD = 270$ ). Although *M. balbus* tadpoles were found in Pinkwood Creek in 1996 (B. Smith pers. comm.) at an elevation of 620 m, since that time *M. balbus* has only been located below 300 m AHD.

The temperature of creek water was less at higher than lower altitudes (Table 4). The temperature of the water in creeks at sites where *M. balbus* had been previously detected ranged from 12 - 21°C (average 16.5°C,  $SD = 3$ ,  $n = 6$ ). The lowest temperatures were at high altitude (above 630 - 700 m AHD) sites in closed forest (ie Pinkwood Creek). Water temperatures at sites with extant populations of *M. balbus* (Big Belimba Creek, Red Creek and Macquarie Rivulet) varied from 17 - 21°C.

The habitat assessment of historic and current *M. balbus* sites indicated an association with:

- second and third order creeks, which ranged from 3-5 m in width (bank to bank),
- creeks that rarely dry out
- substrate that had exposed bedrock or flattened stones
- creeks with a slight gradient (less than 5°)
- creeks that had shallow riffle zones
- at least one side of the creek had a slight gradient
- understorey vegetation that often included Soft Tree Ferns *Dicksonia antarctica*, Rough Tree Ferns *Cyathea australis*, King Ferns *Todea barbara*, Batwing Fern *Histiopteris incis*a and Matt Rush *Lomandra longifolia*.
- the area adjacent to the creek has loam soils and a moderate depth of leaf litter
- fish such as eels, gudgeons and/or galaxia may be present

- the area is rarely burnt

- sympatric species of frog include *L. phylllochroa* (complex), *L. lesueuri*, *L. citropa* and *C. signifera*.

### Monitoring of known *M. balbus* sites

No *M. balbus* tadpoles were observed at Macquarie Pass National Park site. Two *L. nudidigitus* and one *Crinia signifera* called during the survey. Tadpoles of *Crinia signifera*, *L. nudidigitus* and *L. verreauxii* were present. The creek was flowing and since the previous survey sediment was filling the pond where *M. balbus* tadpoles had been detected. No *M. balbus* tadpoles were observed at the sites along Big Belimba Creek.

## DISCUSSION

### Changes in distribution and abundance of *Mixophyes balbus*

A comparison of historic records of *M. balbus* with the sites where the species was detected during the current survey indicated that the species has declined substantially in distribution and abundance since the 1970's. Most of the historic sites surveyed still contained potential habitat. However, no animals were found during the current survey above 300 m AHD (18 of the nocturnal sites and 48 of the diurnal sites).

Surveys of 37 streams in south-eastern NSW for *M. balbus* during the 2000-2001 season only detected one adult and a single tadpole at Big Belimba Creek and five tadpoles at Macquarie Rivulet (Hunter, 2001). No tadpoles were found at these sites during our repeat surveys in 2002.

Historic and current records indicate that *M. balbus* has a fragmented distribution. For example the range, which forms Mumbulla State Forest/National Park, lies to the east of and is distinct from the Great Dividing Range proper. The Mumbulla area is now surrounded by farmland. Hence this population (if extant) is isolated and extremely vulnerable to extinction by factors such as wildfire, logging

and possibly inbreeding depression.

No *M. balbus* were found in the far south (Eden) and south-west (Cann River Highway) of the survey region. These areas have experienced extremes in climate (prolonged drought coupled with flooding) over the last decade (A. Douche pers. comm.). Although conditions during the survey were considered excellent for detecting frogs (warm humid northerly air flow and unsettled weather), several creeks were dry or reduced to pools.

Historically, the species was often found up to 790 m asl in the survey region (M. Littlejohn unpubl. data). Frogs were not found south of Cobargo (36°22'S) in this survey, but were historically detected as far south as the Cann River catchment, Victoria (37°15'S) (Gillespie & Hines, 1999). *Mixophyes balbus* has clearly declined or disappeared from the southern part of its range, and from altitudes above 300 m.

The general absence of *M. balbus* tadpoles (potential recruitment) at two of the three extant sites indicates either a failure to breed or high mortality of eggs/tadpoles. Given the low number of adult frogs and tadpoles the continued survival of *M. balbus* on the south coast of NSW appears tenuous.

### Threatening processes

Potential threatening processes to *M. balbus* are considered to include: disease (infection of frogs or tadpoles by the amphibian chytrid (*Batrachochytrium*) fungus, and eggs by other fungal pathogens), predation of tadpoles (and eggs?) by exotic species of fish, increased losses of tadpoles due to increased frequency and/or magnitude of flood events, destruction or degradation of breeding sites due to changed creek flow regimes, reduction in breeding attempts or success due to increased frequency and/or magnitude of drought events, reductions in water quality due to logging and forest road construction and increases in ultraviolet radiation.

No sick *M. balbus* were found during the present survey. However, the two sick *L.*

*lesueuri*, found at an extant *M. balbus* site, were identified as being infected with amphibian chytrid fungus. *Batrachochytrium* fungus kills free-living amphibians and there is evidence that some frog populations suddenly decline due to mortality caused by amphibian chytrid (Berger et al., 1999). The current detection of *Batrachochytrium* in frog populations on the south coast of NSW indicates that the pathogen is widespread and may have a role in the decline in *M. balbus*.

The death of *L. nudidigitus* eggs and subsequent infection by the fungus *Acremonium* sp. had not been previously documented and may represent another threat to frogs. Although adults and tadpoles of *L. nudidigitus* were common, the presence of dead eggs over such a wide geographic area (from Eden to Narooma) is of concern. There is a need to monitor the rate and distribution of fungus affected eggs in NSW.

Trout were present in the Mongarlowe River and Bemboka River above 680 m AHD. They have been identified as the primary cause of decline in the Spotted Tree Frog *L. spenceri* (Robertson & Gillespie, 1989) and to have impacted on upland populations of Leaf Green Tree Frog *Litoria phyllochroa* (Gillespie & Hero, 1999). Frogs and tadpoles were either uncommon or absent at sites which contained trout. Predation of tadpoles by trout may have caused some of the upland populations of *M. balbus* to decline or disappear.

Rainfall across the region varied widely immediately prior to and during the survey. In the Shoalhaven - Wollongong area, flooding occurred in August and October 1999. The flood had flushed *L. citropa* and *L. lesueuri* tadpoles from creeks (GD pers. obs.). Searches at a historic breeding site of *M. balbus* (Kellets Creek, Nowra) in December 1999 failed to detect tadpoles. Although the absence of tadpoles at Kellets Creek may have been due to other factors, it is possible that *M. balbus* had bred within the last 12 months but the flood had flushed their tadpoles.

The majority of sites from the NSW/Vic. border north to Moruya showed signs of recent large flood events. Woody debris was often piled at a height beside the edge of creeks and logjams were common. Flood-deposited bedload, consisting of coarse sand and small stones, covered hundreds of metres within many creeks, resulting in several becoming superficially dry because flow was occurring under the surface of the bedload. The deposition of this material is indicative of substantial erosion having occurred upstream. Although erosion and deposition are natural events, the presence of large volumes of sand and coarser material in the upper laterals of creeks is indicative of significant upstream land clearing or other changes to the landscape. Furthermore, if potential *M. balbus* breeding locations such as riffle zones and potholes are covered with sediment, it is likely that breeding will not occur until favoured creek morphology is re-established.

### Survey Efficacy

The extremes in rainfall do not appear to have significantly affected the numbers and distribution of other frog species. However, they may have influenced the number of *M. balbus* detected. *Mixophyes balbus* populations may have been slower to recover than other species of frog or were unable to recover, as their populations were too small.

The survey methods were successful in facilitating the detection of *M. balbus*. These methods included site selection by recognition of significant habitat features, diurnal surveys for tadpoles and the broadcast of calls while conducting spotlight surveys. The broadcast of calls while conducting spotlight surveys also elicited responses from other species of frog. Most of the *L. citropa* and *L. nudigigitus* were detected as they responded to the broadcast of *M. balbus*. Hence, the method allowed a more accurate assessment of the presence/absence and density of non-target species.

### Habitat characteristics of sites where

### *Mixophyes balbus* was detected

*Mixophyes balbus* was detected beside creeks bordered by mesic forests that had slight gradients and riffle zones. *Mixophyes balbus* is known to spawn in riffle zones on gravel or leaf litter (Daly, 1998; Anstis, 2002). The only site where tadpoles were located during the current survey was downstream of a culvert, which had a concreted base that formed a shallow riffle area. *Mixophyes balbus* adults have been observed in culverts and tadpoles in pools immediately downstream (GD pers. obs.). Artificial habitat created by culverts may provide potential breeding sites (riffle zones and plunge pools) for *M. balbus*.

### Conservation Measures

To conserve the remaining genotypes of *M. balbus* contained within the southern populations it is recommended that tadpoles from all extant populations be taken into captivity. Tadpoles from each population should be raised separately and the resulting frogs used to establish captive breeding colonies. Our results indicate that this extreme conservation measure is required as a matter of urgency.

The results of the current survey prompted the senior author to nominate south coast *M. balbus* populations for inclusion on Part 2, Schedule 1 of the *Threatened Species Conservation Act (1995)* as Endangered Populations. The Scientific Committee sought additional information regarding *M. balbus* and on 13 December 2002 listed the species on Part 1, Schedule 1 of that Act as Endangered.

### ACKNOWLEDGMENTS

We thank H. Hines, G. Shea, N. Sheppard (NSW NPWS) and A. McIntyre (NSW NPWS) and an anonymous referee for giving comments on earlier drafts. Mr I. Jackett (NSW NPWS) provided the Figures. Ms M. Anstis, Mr A. Douche and B. Smith were very helpful in providing locations where they had found *M. balbus*. The survey was funded by NSW NPWS. Surveys were conducted under Scientific Licence A 999.



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*Litoria citropa* = Lc, *Litoria ewingii* = Le, *Litoria jervisiensis* = Lj, *Litoria nudidigitus* = Ln, *Litoria lesueuri* = Ll, *Litoria peronii* = Lp, *Litoria verreauxii* = Lv, *Crinia signifera* = Cs, *Geocrinia victoriana* = Gv, *Limnodynastes peronii* = Li, *Limnodynastes tasmaniensis* = Lt, *Mixophyes balbus* = Mb, *Paracrinia haswelli* = Ph, *Pseudophryne bibronii* = Pb.

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Altitude AHD	Site	Lc	Le	Lj	Ln	Li	Lt	Mb	Ph	Pb	Diurnal Total Species	Nocturnal Total Species
40	Wallagargh Creek				D						1	-
80	Germans Creek*	D			D						2	-
70	Bruce Creek			D							1	-
110	Old Mill Trail	N, D		N, D							2	3
80	Ludwigs Creek Picnic a	N		N		N, D					1	3
80	Ludwigs Creek Picnic a	N		N		N					-	3
80	Ludwigs Creek	D		D		D					3	-
430	Flat Rock Creek*	D			D	D					4	-
600	Possum Parade Road a *					D			D		2	-
480	Possum Parade Road b *			D		D				D	2	-
470	Hopping Joe Creek Road a *				D							2
420	Hopping Joe Creek Road b *						D					1
450	Genoa River Road	D		D							2	-
840	Burrumbucco Creek	D									1	-
600	Myabra Creek Picnic			D							1	-
770	Waratah Creek							D			1	-
710	White Rock Creek		D	D							2	-
550	Nalbaugh Falls	D		D							3	-
2240	Chalkhills Creek	D			D		D				4	-
40	Knights Creek Mumbulla a *			N				N			-	2
40	Knights Creek Mumbulla b *	D		D	N			N			2	2
100	Crawley Creek	D		D				D			3	-
200	Mumbulla Creek a			N	N, D						1	2



Altitude AHD	Site	Lc	Le	Lj	Ln	Li	Lf	Mb	Ph	Pb	Diurnal Total Species	Nocturnal Total Species
200	Mumbulla Creek b				N						-	2
110	Nadgee Road/Bruces Creek	D		D							2	-
90	Ireland Tims Road a			D							2	-
90	Ireland Tims Road b										0	-
500	Mt Darah Road	D		D							3	-
640	Mt Harroitt's Road			D							1	-
480	Mt Harrett/Careys			D							2	-
900	Fastigata Rd			D							1	-
440	Indooroopilly			D							2	-
200	Good Dog Creek a										0	-
120	Good Dog Creek b										0	-
230	Coopers Gully*										0	-
190	Kings Creek			D							1	-
230	tributary Brogers Creek			D							1	-
390	Tributary Lamonds Creek										0	-
130	tributary Kings Creek										0	-
190	Kings Creek			D							1	-
170	School Creek	D		D							2	-
650	Fitzroy Falls*			D	D						2	-
70	Brogers Creek a				D						1	-
70	Brogers Creek b				D						2	-
160	Ryders Creek										1	-
670	Mongarlowe River			D							1	-

700		N, D	1	1
700	Mongarlowe Creek a *	N	0	1
700	Mongarlowe Creek b *	D	1	0
700	Mongarlowe Creek c *			
730	Tributary Mongarlowe River a *			
680	Tributary Mongarlowe River b *	N		0
690	Tributary Mongarlowe River c *			1
60	Tributary Gulph Creek	D	2	0
120	Waterloo Creek	D	1	-
130	Pipeclay Creek	D	1	-
100	Cuttagee Creek a	D	2	-
10	Cuttagee Creek b	D	1	-
40	Myrtle Creek a	D	1	-
40	Myrtle Creek b	D	1	-
30	Nutleys Creek	D	1	-
20	Digmans Creek a	D	2	-
50	Digmans Creek b		0	-
40	Digmans Creek c		0	-
60	Digmans Creek d		0	-
80	Upper Digmans Creek	D	2	-
70	Yellow Clay Creek	D	2	-
60	tributary Red Bank Creek		0	-
60	Red Bank Creek a	D	1	-
80	Red Creek a	D	2	-

Altitude AHD	Site	Lc	Le	Lj	Ln	Li	Lp	Lv	Cs	Gv	Li	Mb	Ph	Pb	Diurnal Total Species	Nocturnal Total Species
60	Red Creek b	N	N		N	N			N						-	5
60	Red Creek c				N	N	N		N			N			-	5
100	Wandella Creek a					D			D						2	-
100	Wandella Creek b					D									1	-
110	Welshes Creek					D									1	-
130	Bumbo Creek a				N	N									-	2
130	Bumbo Creek b				N	N, D									1	2
630	Pinkwood Creek a *														-	0
630	Pinkwood Creek b *					D									1	0
280	New England Creek a	N			N	N			N						-	4
280	New England Creek b	N			N	N			N						-	4
280	New England Creek c	N	N, D		N	D			N, D		N				3	5
50	Reedy Creek					D									1	-
50	Red Bank Creek b					D									1	-
30	Cobrack	D													1	-
30	Lawlers Creek a														0	-
10	Lawlers Creek b	D			D	D									3	-
40	Lawlers Creek c														0	-
40	Lawlers Creek d				D										1	-
180	Bemboka River a	D				D									2	-
940	Bemboka River b				N										0	1
900	Bemboka River c														0	0
1010	Bemboka River d														0	0



Altitude AHD	Site	Lc	Le	Lj	Ln	Li	Lp	Lv	Cs	Gv	Li	Lt	Mb	Ph	Pb	Diurnal Total Species	Nocturnal Total Species
980	Bemboka River e															-	0
330	Pollacks Flat Creek															0	-
370	Yankees Gap Road				D											1	-
350	Yankees Creek	D			D	D										3	-
980	Fastigata Road															0	-
400	Pollocks Flat Creek a				D											1	-
310	Pollocks Flat Creek b															0	-
180	Bemboka River					D										1	-
340	Yankees Creek				D	D										2	-
370	Basin Creek crossing a		D		D	D										3	-
380	Basin Creek crossing b		D		D	D										3	-
480	Six Mile Creek				D	D										2	-
490	Mt Harriett Fire Trail	N, D			N, D, N, D				N, D							4	4
50	Bangalee Creek b			D												1	-
40	Bangalee Creek c	D			D											2	-
30	Coila Creek a		D		D									N		2	1
30	Coila Creek b			N												0	1
40	Coila Creek c			N, D							N					1	2
40	Coila Creek d															-	0
730	McCarthy's Creek a															0	-
710	McCarthy's Creek b				N, D											1	1
710	McCarthy's Creek c															-	0
720	Reisdale Creek								D			D	D			3	-

Altitude AHD	Site	Lc	Le	Lj	Ln	Ll	Lp	Lv	Cs	Gv	Li	Lt	Mb	Ph	Pb	Diurnal Total Species	Nocturnal Total Species
720	tributary Mongarlowe River a *									D							1
	tributary Mongarlowe River b					N											-
690	Sheep Station Creek*															0	1
70	Kenneys Creek a	N		N	N	D, N	N		N		N					1	5
80	Kenneys Creek b					N	N									-	2
50	Cabbage Tree Creek					D			D							2	-
10	Paradise Creek															0	-
80	Nelligen Creek					D										1	-
50	McCardy Creek			D		D										2	-
50	Currowan Creek					D										1	-
200	Carters Creek					D										1	-
50	Lyons Creek a			D, N	N	N										1	2
60	Lyons Creek b			N	N	N										-	2
310	Bundanoon Creek			D	D	D										2	-
300	tributary Macquarie Rivulet			D, N	N	N		D					D, N			3	2
300	Macquarie Rivulet			N	N	N											2
650	Fitzroy Falls			D												1	-
460	Mount Drumedary															0	-
700	Mongarlowe River a *					N										-	1
700	Mongarlowe River b *					N										-	1
640	Careys Creek	N		N	N	N			N							-	4
640	Careys Creek	N		N	N	N										-	3
640	Wyndham Road			N	N	N										.	2

Altitude AHD	Site	Lc	Le	Lj	Ln	Li	Lp	Lv	Cs	Gv	Li	Lt	Mb	Ph	Pb	Diurnal Total Species	Nocturnal Total Species
230	Buckjumba Creek			N	N	Z			Z							-	3
230	Buckjumba Creek	N		N	N	Z			Z							-	4
230	Buckjumba Creek	N		N	N	Z			Z							-	4
30	Currowar Creek															-	0
60	Dwyers Creek										N					-	1
490	Snowy Mountains Highway															-	2
250	Trapyard Creek	N	N	N	N	Z			Z							-	5
30	Fern Creek			N	N				N							-	2
110	Welsh's Road Creek			N	N	Z			Z		N					-	4
30	Myrtle Creek a	N				Z					N					-	3
30	Myrtle Creek b	N				Z			Z							-	3
30	Nutlet's Creek a					Z			Z							-	2
30	Nutlet's Creek b	N				Z			Z							-	3
230	Big Belimba Creek a			N												-	1
230	Big Belimba Creek b			N					Z							-	2
230	Big Belimba Creek c *			N					Z				N			-	4
230	Big Belimba Creek d *					Z							N			-	2
470	Goodenia Rainforest a															-	0
470	Goodenia Rainforest b			N												-	1
140	Rats Valley Road a			N		Z		N								-	4
140	Rats Valley Road b								Z							-	1
220	Minnamurra Rainforest a					N										-	1
220	Minnamurra Rainforest b															-	0



Altitude AHD	Site	Lc	Le	Lj	Ln	Li	Lp	Lv	Cs	Gv	Li	Lt	Mb	Ph	Pb	Diurnal Total Species	Nocturnal Total Species
230	Minnamurra Rainforest c				N											-	1
230	Minnamurra Rainforest d															-	0
140	Nullica Creek			N	N				N							-	3
60	Myrial River Road			N	N				N							-	3
170	Old Hut Creek a	N							N							-	3
170	Old Hut Creek b	N		N	N				N							-	4
100	Merricumbene Creek			N	N											-	2
40	McCrady's Creek a			N	N				N							-	3
40	McCrady's Creek b			N	N				N							-	3
40	McCrady's Creek c			N	N											-	2
70	Main Creek a			N												-	1
70	Main Creek b			N	N											-	2
70	Diante Creek a			N												-	1
70	Diante Creek b			N												-	1
Diurnal	Species Relative Abundance	22	7	1	56	46	4	3	25	3	2	1	1	1	0	N = 130	
Nocturnal	Species Relative Abundance	23	4	0	63	43	1	1	36	0	6	0	4	0	1	N = 84	

**Table 2. Total number of frogs detected during searches for *Mixophyes balbus*.**

*Litoria citropa* = Lc, *Litoria ewingii* = Le, *Litoria nudidigitus* = Ln, *Litoria lesueuri* = Ll, *Crinia signifera* = Cs, *Limnodynastes peronii* = Li, *Mixophyes balbus* = Mb, *Pseudophryne bibronii* = Pb.

Species	Lc	Le	Ln	Ll	Cs	Li	Mb	Pb	Total
<b>Total</b>	50	2	200	90	103	12	3	2	462
<b>% total</b>	11	0.4	43	19	22	2.3	0.6	0.4	

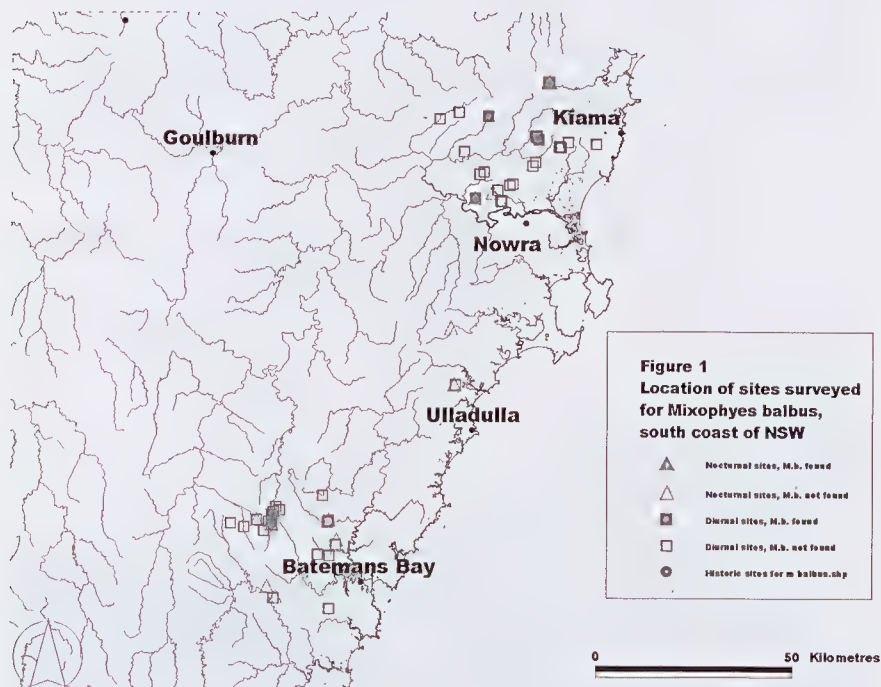
**Table 3. Sites where *M. balbus* has been detected in south-eastern NSW.**

Site/Topographic Map	Year	Recorder	Alt.	Vegetation
Macquarie Rivulet, Robertson	2000	G. Daly	300	<i>Acacia maidenii</i> , <i>Toona ciliata</i> , <i>Pittosporum undulatum</i> , <i>Cyathea australis</i> , <i>Lomandra longifolia</i>
Red Creek, Cadgee	2000	M. Pennay	60	<i>E. viminalis</i> , <i>Casuarina cunninghamiana</i> , <i>Backhousia myrtifolia</i>
Big Belimba Creek, Nerrigundah	1998+00	Daly/Pennay	230	<i>E. elata</i> , <i>Dicksonia antarctica</i> , <i>Todea barbara</i>
Kellets Creek, Burrier	1996-8	G. Daly	50	<i>Syncarpia glomulifera</i> ; <i>E. botryoides/saligna</i> , <i>Todea barbara</i>
Germans Creek, Timbillica	1996	State Forests	80	<i>E. cytellocarpa/E. sieberi</i> , <i>Lomandra longifolia</i>
Stoney Creek, Timbillica	1996 ?	State Forests	60	<i>E. cytellocarpa</i> , <i>Lomandra longifolia</i>
Pinkwood Creek, Nerrigundah	1996	B. Smith	630	<i>Eucryphia moorei</i> , <i>D. antarctica</i> , <i>T. barbara</i>
Coopers Creek, Kangaroo Valley	1995	G. Daly	230	<i>E. botryoides/saligna</i> , <i>Syzygium australe</i> , <i>Dendrocnide excelsa</i>
Knight's Creek, Brogo	1995	A. Douche	40	<i>E. viminalis</i> , <i>Backhousia myrtifolia</i>
Hopping Joe Creek, Nungutta	1980	G. Webb	420	<i>E. cytellocarpa</i> . Now a thin corridor in <i>Pinus radiata</i>
Mongarlowe River, Monga	1977	CSIRO	700	<i>E. fastigata</i> , <i>Dicksonia antarctica</i> , <i>Todea barbara</i>
Flat Rock Creek, Nungutta	1975?	M. Littlejohn	450	<i>E. cytellocarpa</i> , <i>Lomandra longifolia</i>
trib. Mongarlowe River, Monga	1975	M. Littlejohn	790	<i>E. sieberi</i> , <i>E. radiata</i> , <i>Gléichenia</i> sp.
Glow Worm Glen, Bundanoon	1963	Aust. Mus.	610	no information
Fitzroy Falls, Bundanoon	1974	M. Mahony	650	<i>E. sieberi</i>

**Table 4. Temperature of water in creeks where *M. balbus* had been detected.**

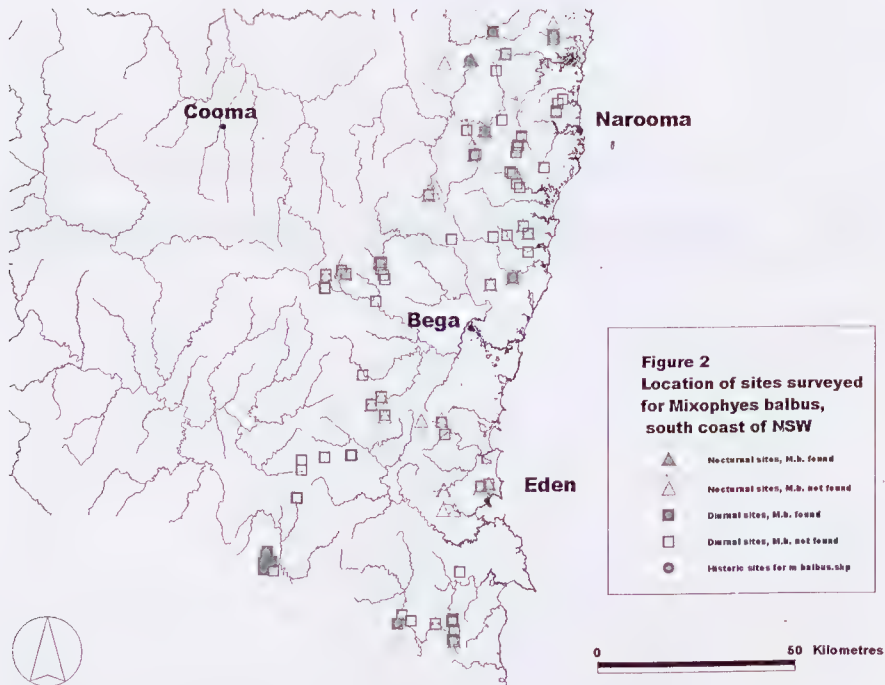
Site	Altitude (m)	Date	Temperature (°C)
Kellets Creek	50	31.1.00	16.2
Red Creek	60	16.1.00	21.0
Big Belimba Creek	230	14.1.00	17.1
Macquarie Rivulet	300	17.2.00	17.5
Pinkwood Creek	630	17.1.00	11.7
Mongarlowe River	700	1.2.00	15.2

**Figure 1. Location of sites surveyed for *Mixophyes balbus*, south coast of New South Wales.**





**Figure 2. Location of sites surveyed for *Mixophyes balbus*, south coast of New South Wales.**



# HERPETOLOGICAL NOTES

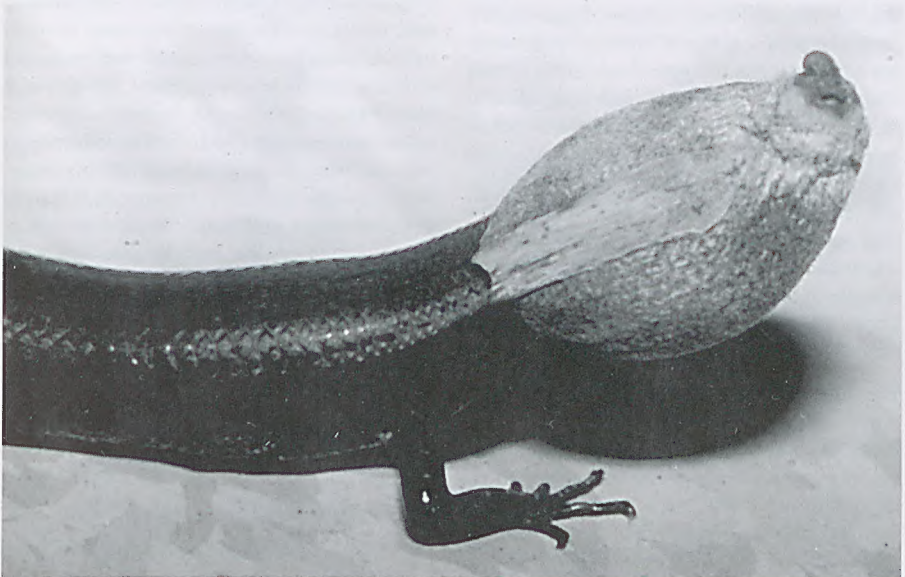
## ORNAMENTAL PLANT TRAPS LIZARD

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Biological Sciences A08, University of Sydney, NSW 2006 Australia

Suburban gardens contain a diverse array of non-Australian plant species, some of which may pose potential dangers to native fauna. We encountered such a case on 6 May 2002, when an adult garden skink (*Lampropholis delicata*) was found in the grounds of the University of Sydney, with its head firmly wedged inside the dried seed-cap of an ornamental plant "Lassiandra" (*Tibouchina* 'Alstonville'). This plant produces bright purple flowers and is widespread in Sydney gardens. The lizard (adult female, 40.5 mm snout-vent length, 76 mm total length, mass 0.89 g) had its entire head wedged into the hard, dry seed-cap (11.9 mm long, 8.7 mm wide). The seed-cap was slightly flattened, perhaps as a result of being stepped on by a student. Whatever the

process, the result was that the cap's inwards-projecting flange became tightly wedged around the lizard's neck (Fig. 1). We had to cut the cap to release the lizard, and it seems likely that the animal would have faced a lingering death without this intervention. We have seen similar problems with snakes and lizards caught by the head in wire fences, discarded beer and soft-drink cans, or plastic packaging materials. However, this is the first time we have seen a lizard trapped by a plant. It emphasises the subtle and diverse ways in which human interference and especially, introduction of exotic species, can pose dangers to native animals.

**Figure 1. Adult garden skink (*Lampropholis delicata*) trapped by the dried seed-cap of an ornamental plant.**



## BOOK REVIEW

### AMPHIBIAN MEDICINE AND CAPTIVE HUSBANDRY

Edited by Kevin M Wright and Brent R Whitaker, 2001.  
499 pp., 243 colour photographs, 317 black and white figures, 54 tables.

Published by Krieger Publishing Company, Malabar, Florida, USA.  
R.R.P. US\$140. ISBN 0-89464-917-5 (hardcover)

The husbandry and medicine of amphibians is an exciting and rapidly expanding field. As Wilbur Amand writes in the foreword to this book "...until now there has been no text fully devoted to the health and diseases of these fascinating creatures". The editors and principal authors, Kevin Wright and Brent Whitaker, have done an excellent job compiling this book. They have provided us with a one volume encyclopaedia on amphibian health and husbandry. An impressive precedent has been set – this book will be a welcome addition to any herpetologist's library.

The scientific material within the book is well written and conveys detailed information in an easily digested manner. The book is, on the whole, well-organised and there is an impressive list of contributing authors. There are 27 chapters covering topics such as taxonomy, anatomy, physiology, husbandry and housing, diets, nutritional disorders, clinical techniques, clinical microbiology, haematology, water quality, bacterial diseases, parasitology, toxicology, imaging, the amphibian eye, surgery, reproduction, therapeutics and necropsy. Drawings and illustrations are impressive and are well placed throughout to complement the text. There are a further 44 pages of colour plates in the centre of the book.

The text contains much useful introductory information on taxonomy, biology and physiology. With an appropriately strong emphasis on captive husbandry and environment, both herpetologists and vets will find much detailed and extremely useful information in these sections. We are constantly reminded of

the importance of excellent husbandry and the vital connection between good husbandry and good health.

The book covers many topics at a variety of levels, from the basic to the extremely technical. For example, Chapter 8 "Clinical techniques" contains much practical information. The succinct descriptions of basic handling techniques are well-supported by photographs and diagrams. Even simple procedures such as weighing the amphibian are covered in beautifully practical terms. The most experienced herpetologist will gather several handy new suggestions from this chapter alone.

Much of the information in this book has been drawn from North American experience and literature. This should be borne in mind by Australasians when using the book. As with any rapidly growing field of interest, new knowledge may quickly render technical information superceded. Some information will doubtless be outdated even at this stage, but this book definitely represents the most comprehensive and useful text in the field of amphibian medicine and husbandry. I am certain that this book will be a definitive text for years to come.

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## NOTES TO CONTRIBUTORS

*Herpetofauna* publishes articles on any aspect of reptiles and amphibians. Articles are invited from interested authors particularly non-professional herpetologists and keepers. Priority is given to articles reporting field work, observations in the field and captive husbandry and breeding.

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Authors are responsible for the accuracy of the information presented in any submitted article. Current taxonomic combinations should be used unless the article is itself of a taxonomic nature proposing new combinations or describing new species.

Original illustrations will be returned to the author, if requested, after publication.

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Two copies of the article (including any illustrations) should be submitted. Typewrite or handwriting (neatly) your manuscript in double spacing with a 25mm free margin all round on A4 size paper. Number the pages. Number the illustrations as Figure 1 etc., Table 1 etc., or Map 1 etc., and include a caption with each one. Either underline or italicise scientific names. Use each scientific name in full the first time, (eg *Delma australis*), subsequently it can be shortened (*D. australis*). Include a common name for each species.

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Latitude and longitude of any localities mentioned should be indicated.

Use the Concise Oxford Dictionary for spelling checks.

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The senior author will receive 25 reprints of the article free of charge.



Grass skink (*Lampropholis delicata*) trapped in the seed case of an ornamental plant.  
See paper on page 131. (Photo by T. Langkilde).



Bleating Tree Frog (*Litoria dentata*) from Brunswick Heads, NSW  
See paper on page 93. (Photo by G. Shea).